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No. 61, 44 pages, 11 figures. February 28, 1967.

AUTOTOMY IN THE MOLLUSCA

By

Charles R. Stasek
California Academy of Sciences

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INTRODUCTION

When under duress many animal species have the ability to cast off particular portions of the body. Probably everyone is aware that a lizard can easily shed its tail and that a crab can drop its legs. Less well known are analogous instances in the Mollusca, the group with which the present paper is concerned and in which the phenomenon has been reported in representatives of four of the six living classes. Unfortunately, there seems to be no complete study of this ability in any single molluscan species, with the occurrence of abscission often obscurely buried among other data, given a variety of names, or not related to previous investigations.

From a review of the literature, I have concluded that an underlying reason for the present paucity of knowledge in this area has been that there does not exist a clearly expressed framework of ideas within which comparative investigations can be carried out; hence, the aim of the present paper is not only to bring together and to illustrate instances of the process in the Mollusca, but also to set what is known about each instance against several conditions that one might expect to be associated with this ability wherever it occurs. In this way one can compare and evaluate existing and, hopefully, as yet unreported information on anatomical, physiological, behavioral, and ecological factors that make the usually violent loss of living tissue adaptively significant to the organism.

Except for bringing this material together with a definite purpose in mind and including some speculation, original contributions in this paper are limited to notes concerning the siphons of the bivalve *Solen sicarius* Gould, 1850.

HISTORICAL RÉSUMÉ

The act by which an animal casts off a portion of its own body was termed *"autotomie"* (="autotomy") by Fredericq (1883, who, in 1882 (a and b) demonstrated in a crab and in a lizard that such loss was the result of a muscular reflex action initiated by stimulation of sensory nerves in the part to be lost. In 1886, the same author summarized the occurrence of autotomy in reptiles and arthropods and characterized its significance as one of escape from enemies. "Le sacrifice d'une partie du corps assure, dans ce cas, le salut du tout" (p. 613). He also suggested that a comparable situation existed in echinoderms and predicted that one might encounter autotomy in all animals of small size with hard and slender extremities.

In the same year Varigny (1886) remarked that it would be interesting to know if activity equivalent to autotomy in crustaceans occurs in other animal groups. Again in the same year, Oehlert (1886) became the first person to associate autotomy with conditions previously known to exist in certain Mollusca. Oehlert was unaware that a more complete summary of mol-

luscan examples had been made by Crosse (1860), whose review predates inception of the word "autotomy."

In 1887, Fredericq tabulated the taxa he knew to be characterized by autotomy, reserving the term for those instances of active self-mutilation brought about by accidental external circumstances. Losses of portions of the body resulting from purely internal stimuli, such as proliferation of mature proglottids in tapeworms and release of the hectocotylized arm in male cephalopods, were not held by Fredericq to be examples of autotomy. Parallel with these phenomena Fredericq ranked the laying of eggs and mammalian parturition. Giard (1887) noted that the table given by Fredericq was incomplete, and classified instances of autotomy according to function rather than according to taxonomic occurrence. His outline, as more clearly organized by Riggenbach (1903, p. 851), is as follows:

I. DEFENSIVE AUTOTOMY

A. *Evasive autotomy,* in which the result is escape from enemies.

B. *Economic autotomy,* in which the result is reduction of the animal's volume under unfavorable nutritive or respiratory conditions. While economic autotomy may occur in nature, it is usually observed only under imperfect laboratory situations.

II. REPRODUCTIVE AUTOTOMY, in which the result is reproduction. This category included hectocotylization of male cephalopods and, at the end of the series, release of proglottids by tapeworms.

III. PARASITIC AUTOTOMY, in which the animal rids itself of parasites as in *Asterias richardi,* which severs rays infected by myzostomid worms. [This category was added in a later paper. See Riggenbach (1903, pp. 805, 851).]

Here, to help complete the above classification, Giard could have placed an additional category:

IV. ONTOGENETIC AUTOTOMY, in which the developing organism reaches a stage wherein a previously functional element is discarded, such as the early shell and operculum of nudibranchs and the early shell whorls of many gastropods (Pelseneer, 1935, p. 375). Unlike categories I-III, in no instance of ontogenetic autotomy would the animal be expected to regenerate the element.

Giard pointed out that these divisions are not rigorous; for example, autotomy of an evasive type in a starfish is a kind of fission and may result in reproduction. He also offered other classifications of autotomy such as "regenerative" versus "non-regenerative," and "general," where separation occurs at any point on the body, versus "localized," where separation always occurs at a precise point. Giard recognized a gradient of auto-

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tomy into the cellular level, as in the release of nematocysts and in the explusion of gametes. Giard's views were much broader than those of Fredericq and obscure the important distinction that Fredericq made between losses sustained as results of external or internal stimuli.

A paper by Riggenbach (1903) remains the most extensive and most thoughtful review of autotomy throughout the animal kingdom, including the Mollusca. He realized that the visible act of autotomy could not be dissociated from a host of correlated factors, all of which comprise the condition of autotomy. Because of his significance to the study of autotomy, I have paraphrased some of his views below:

Riggenbach defined autotomy as an activity of animals in which a part of the body, an organ, or, generally speaking, a specific mass of living substance is completely detached from the body (p. 858). He considered that autotomy occurred in three easily distinguishable categories. There are animals in which the entire body undergoes violent motion when a part of it autotomizes, others remain quiet with only the piece to be autotomized being excited, others do not move at all. In the first case it is a question of the activation of all or most of the muscles of the body; in the second, of the work of certain muscles lying in the zone of amputation; and in the third, of the action of one or a few specialized *"Brechmuskels"* that exclusively serve the autotomy. These categories are not always sharply distinguishable (p. 858).

Riggenbach stated that, as a rule, autotomy takes the following course: Certain stimuli excite the nervous system. This sets either all the muscles of the body, a single group, or only the specialized *"Brechmuskels"* in action. The activity of the muscles under the influence of the stimuli results of the stimuli results in the detachment. The resulting injury is rendered harmless through muscles or through other definite arrangements. The provisional closure is soon followed by healing of the wound and the regeneration of the lost piece of the body. With termination of regeneration the process of autotomy is concluded (p. 859). Autotomy was noted to occupy usually only a few seconds or minutes, more seldom hours or days, and it can be repeated at short time intervals (p. 861). Riggenbach did not regard as autotomy such processes as moulting, shedding of teeth and antlers, processes associated with metamorphosis, parturition, or release of genital products (p. 884).

Instances of autotomy in the Mollusca were cursorily enumerated by Cooke (1895), Pelseneer (1906, 1935), and Allan (1941).

It must be obvious to anyone who has reviewed the literature on autotomy that, from the historical approach, exactly what is and what is not to be considered an act of autotomy is difficult to say. Practically any event in which an anatomical loss is experienced could find categorical precedence in having been said to be autotomous. Diverse processes from re-

lease of nematocysts by coelenterates, to asexual division in some polychaete annelids (Berkeley and Berkeley, 1954, p. 329), to shedding of the larval shell of nudibranchs (Pelseneer, 1935, p. 375), and to loss of a lizard's tail have all come under the term.

Riggenbach (p. 889) suggested that the term *"Autoperose,"* from the Greek for "I mutilate myself," might be used to encompass all such processes. The term "autotomy" could then be employed more as Fredericq originally intended; namely, to include losses sustained as the result of external stimuli, serving the broad function of escape, and with the animal having some degree of preparedness to facilitate the loss. I favor this view, and would thus exclude ontogenetic losses and, particularly, losses of secreted structures such as the larval shell of nudibranchs and the sheet of dorsal cuticle covering the nudibranch *Corambe pacifica,* as described by MacFarland and O'Donoghue (1929). I would restrict autotomy to the organismic level and not apply it to losses at the cellular level, although cellular processes play an important role in autotomous activity.

CONDITIONS OF AUTOTOMY IN THE MOLLUSCA

From a theoretical standpoint, autotomy within the Mollusca might be expected to have the following characteristics:

1. There should be an ecological stimulus that triggers the severance. Disturbance by field collectors may induce autotomy. This reaction would suggest that disturbance by natural enemies also occurs.

2. The autotomized portion should be an extremity of the body exposed to the triggering stimulus.

3. The part stimulated should be the part lost; therefore, the body wall should be included in the process of severance. Hence, autotomy has been distinguished from evisceration, as occurs in sea cucumbers (Hyman, 1955, p. 205.)

4. The autotomized portion should be dispensible, not containing organs vital to continued existence of the organism as a whole.

5. There should be a restricted zone of weakness at which severance occurs. At least there should exist a predisposition for abscission, perhaps unlocalized, in the part to be autotomized.

6. Severance should be aided by specialized anatomical conditions, for example, sphincter muscles, which come into activity under the proper circumstances.

7. There should be structural or physiological adaptations preventing loss of body fluids and promoting healing of the resultant wound.

8. The body should have the capacity to regenerate a structure resembling that lost, with only a relatively brief period of time needed for completion of regeneration.

9. The severed portion, while unable to regenerate an entire organism, as occurs in some asteroids, might have limited capacity for independent, perhaps violent movement, the function being that of a decoy.

10. There might be additional behavioral specializations facilitating escape of the organism.

11. The loss should be functionally advantageous to the individual, as well as to the species as a whole. In any instance, autotomy should be interpretable as having arisen in evolution through the selective advantages conferred by ability to sustain the loss.

INSTANCES OF AUTOTOMY IN THE MOLLUSCA

In the following account, and so far as present knowledge allows, each example of molluscan autotomy has been presented with the above points in mind. A synoptic table of autotomy in the Mollusca may be found on page 29. Where knowledge is restricted to fact of occurrence alone, references are usually limited to the Synopsis.

GASTROPODA

Prosobranchia

Passing statements that *Harpa ventricosa* (fig. 1) can autotomize the posterior quarter or third of the foot occur often in the literature, but the only information on the process seems to be that contained in the original reports by Quoy and Gaimard (1832, p. 617) and Reynaud (1834). According to the former authors, autotomy is easily induced in this species and is initiated by contractions of the foot, the separation resembling an ungluing rather than a tearing of tissues. On the intact organism they saw no line indicating the potential region of separation, but a large blood sinus traversing the foot suggested a zone of weakness. The muscle fibers anterior to the sinus are longitudinal, while behind it the tissue was said to be homogeneous and like lard. The rejected mass was seen to contract independently for some moments, and they held that a new member is regenerated despite the large volume of tissue to be produced.

Reynaud's observations differ but slightly from those of Quoy and Gaimard. He noted in the single specimen available to him that a shallow transverse furrow marked the position at which autotomy occurred and that the animal of *Harpa* is too large to be entirely retracted into its shell. When the living specimen was placed in alcohol it contracted violently, a tear rapidly progressing from the left side of the foot for more than an inch along the transverse furrow. Death, however, prevented completion of autotomy. Reynaud speculated that if a natural enemy should attack a harpa, the snail

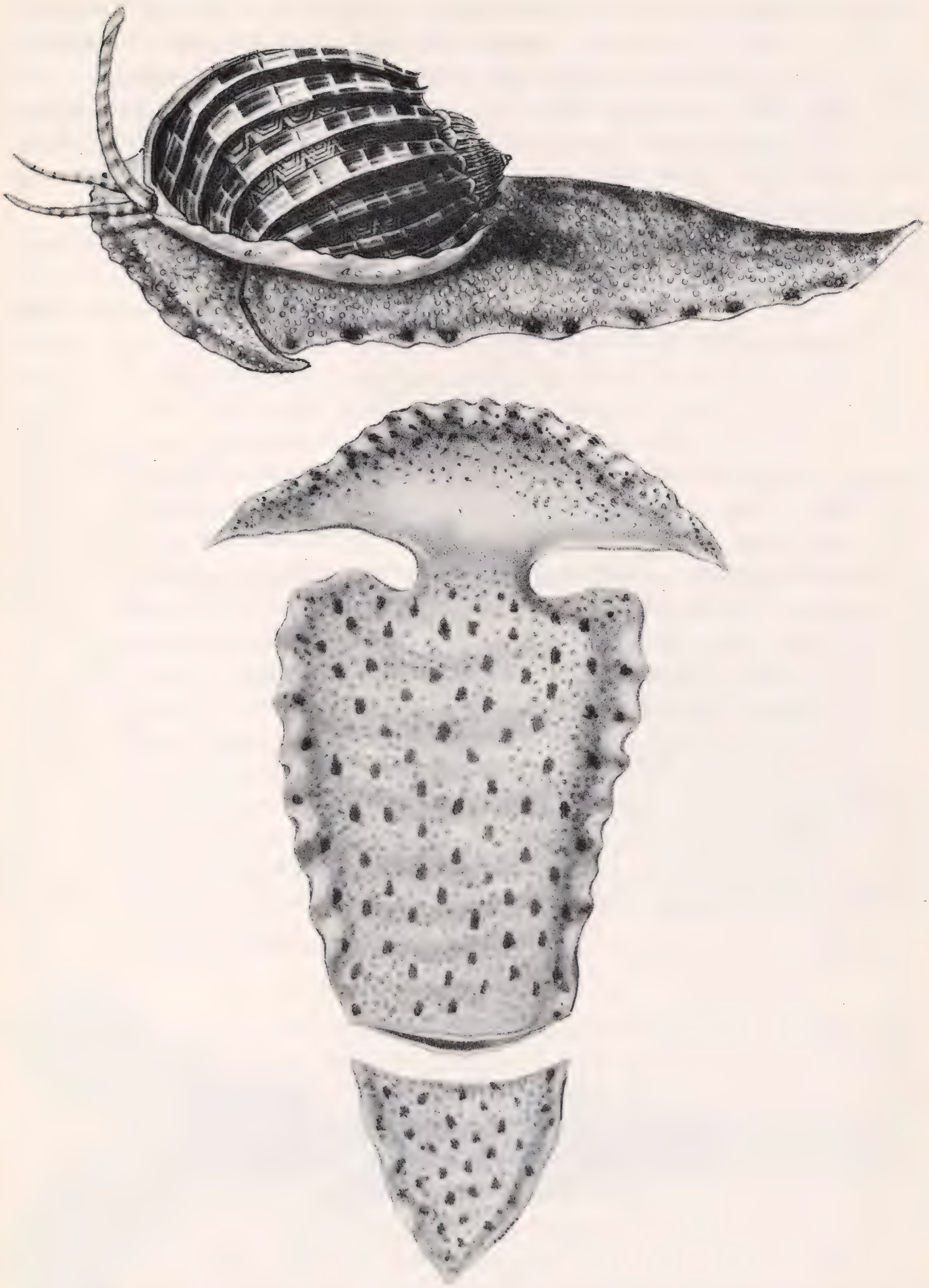


FIGURE 1. *Harpa ventricosa*. Animal from the left side, and (below) ventral aspect of the foot showing autotomized posterior portion. (From Quoy and Gaimard, 1833, pl. 42.)

would withdraw into its shell with the posterior part of the foot protruding, since the shell is too small to accommodate that organ fully. The exposed part, being firm, would protectively close the aperture of the shell in much the same way as would an operculum, which harpa lacks. Should the aggressor prove redoubtable, it seemed probable to Reynaud that rupture of the foot would then occur at the transverse furrow, and the animal would be able to withdraw completely into the shell, thus effecting escape.

That the end of the foot in *Harpa* may be cut off by pressure of the shell was suggested by Cooke (1895).

Adams and Adams (1858, p. 436) reported that "*Stomatia,* like *Harpa* ..., has the power of spontaneously throwing off the hind part of the foot when the animal is irritated, and *Gena* exhibits the same peculiarity; specimens in spirits have the foot usually truncated from this cause." Hedley (1902, p. 100) observed under more natural conditions that "As the conchologist crooks his finger round a live *Stomatella mariei,* the creature falls asunder... *Gena* does the same in Sydney harbor..." The following information concerning these trochids comes from Mr. Robert Talmadge (personal communication) who received it from collectors in the Indo-Pacific region: Animals of the *Stomatella* group spontaneously cast off the posterior part of the foot when there is delay in placing collected specimens in water. The cast portion wriggles and, under natural conditions, is probably a decoy for any predator, the identity of which is unknown. The animals regenerate the cast portion, as Mr. Talmadge has observed small buds protruding from the healed posterior surface of the foot. Most recently, Fishelson and Qidron-Lazar (1966) reported pedal autotomy in *Gena varia.* A fine, transverse white zone that is histologically distinct from adjacent regions marks the site of autotomy. The severed part of the foot undergoes continued movements for 2 to 6 hours following autotomy, but the animal proper does not

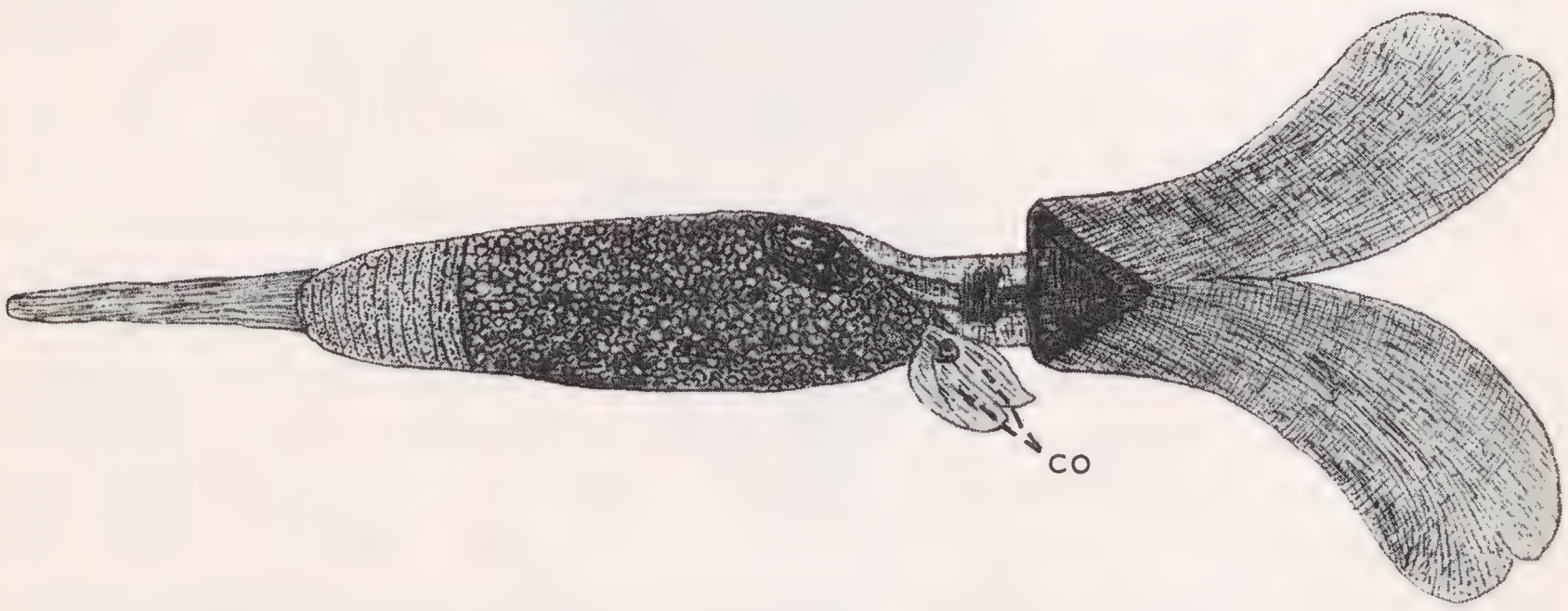


Figure 2. *Herse columnella.* Animal from which shell and mantle have been removed. Cervical organ (co). (From Tesch, 1946, fig. 12.)

immediately attempt escape. Instead, hidden under its shell, it remains firmly attached to a nearby stone.

It should be noted that prior to autotomy all these shelled gastropods have bodies too large to be entirely contained within the shell, while afterwards the shell completely covers the soft parts. This also applies to the land snail *Helicarion* to be described below.

Knowledge of autotomy of the posterior end of the foot of *Haliotidea (=Calyptraea)* is limited to mere mention by Pelseneer (1935, p. 375), who attributed the information to Adams, whose observations I have not been able to locate.

Opisthobranchia

Pteropoda

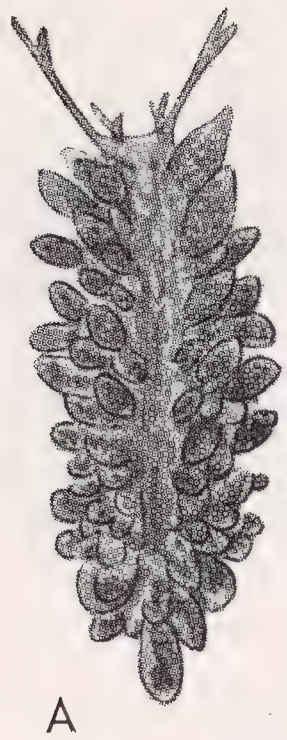
The phallus of protandrous species of benthic gastropods is resorbed during sexual transition from the male to the female phase (Coe, 1944, p. 88). In contrast, Bonnevie (1916), followed by Tesch (1946, p. 23), noted in the thecosomatous pteropod *Herse columnella* that the penis and its associated cervical organ (fig. 2, co) are thrown off from a definite pre-formed spot at the base of both organs. This species is protandrous with the loss of the copulatory apparatus occurring sometime after the female stage is entered and copulation accomplished. Since these organs are not regenerated, this condition might best be considered an ontogenetic loss.

The question arises as to why the copulatory apparatus should be thrown off rather than resorbed as in benthic species. The highly speculative answer may be that the fertilized female experiences, and thus benefits from reduced specific gravity and increased swimming ability incurred through immediate loss of the organs, even though these are small and differences must be slight.

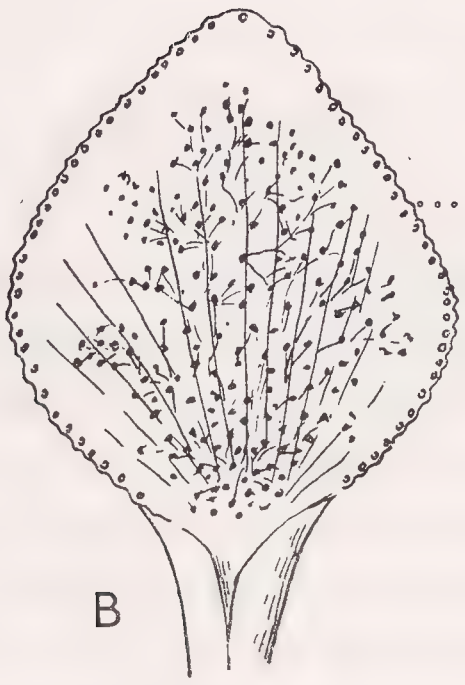
Sacoglossa

Gonor (1961, p. 390) observed that a portion of the foot may be cast when the Mediterranean species *Lobiger serradifalci* is roughly handled. "A clearly discernable dehiscence line can be seen at the base of the [parapodial] lobes and foot tail. This is the site where separation from the body takes place." Contraction at this site occurs in a sphincter-like manner.

Caliphylla australis (fig. 3, A) was observed by Risbec (1928, p. 273) to have cerata that adhere strongly to the observer's finger while detaching from the body of the gastropod. Thus isolated, the cerata live several hours and move about in the water while writhing vigorously. The margin of each ceras is lined with defensive glands, each major gland being surrounded by accessory glands (fig. 3, B and C). Risbec postulated that if an animal should attack this species, *Caliphylla* would be able to defend itself by



A



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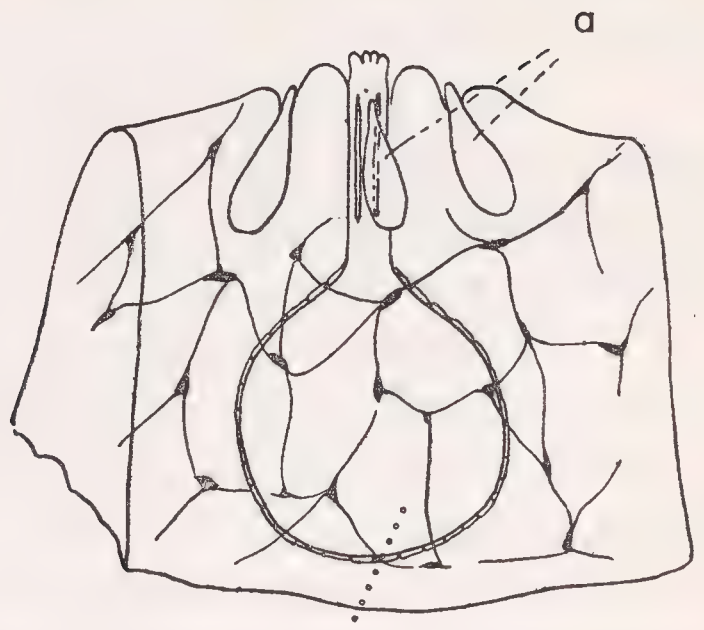

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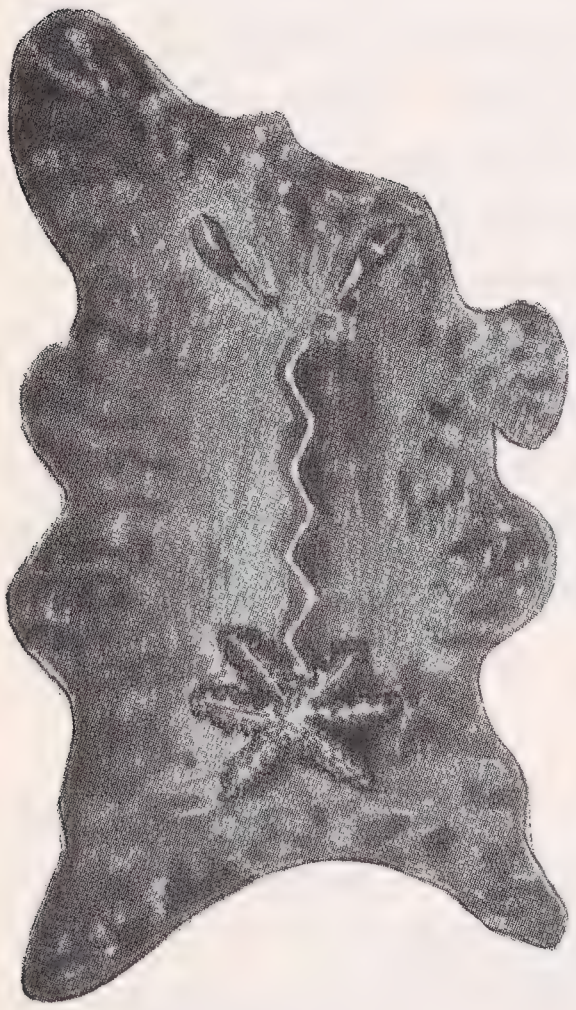

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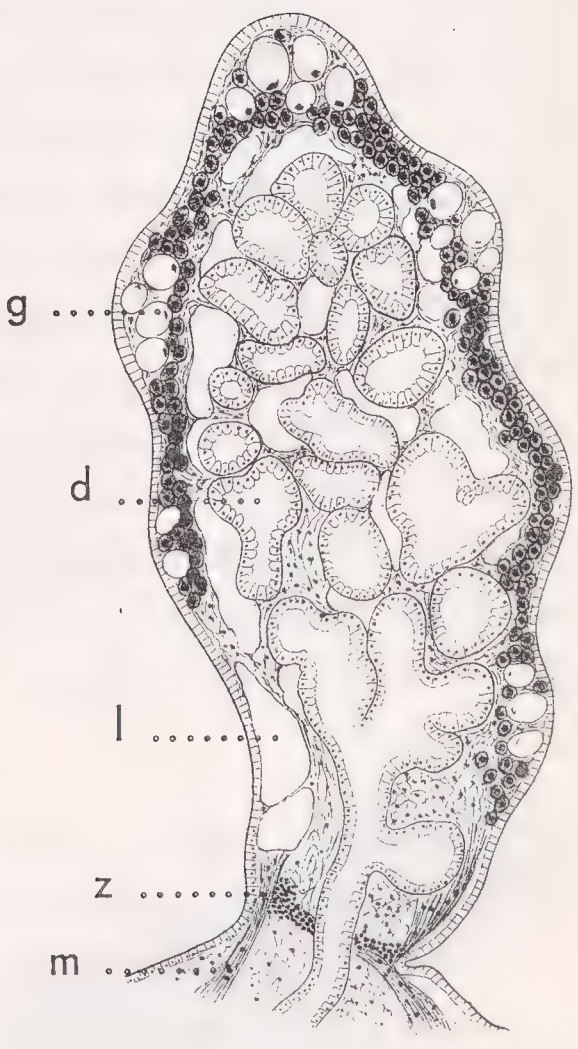

E

Figure 3. **A**, *Caliphylla australis*, dorsal aspect. **B**, *C. australis*, one of the cerata with marginal row of defensive glands. **C**, *C. australis*, enlarged aspect of a defensive gland; principal gland (**p**), accessory glands (**a**). **D**, *Asteronotus boholiensis*, dorsal aspect showing irregular mantle margins resulting from autotomy. **E**, *Doto coronata*, longitudinal section of a ceras showing defensive glands (**g**), sections of digestive diverticula (**d**), blood spaces (**l**), muscles (**m**), and the zone presumed to have a function associated with autotomy of the ceras (**z**). (**A-D**, from Risbec, 1928; **E**, from Hecht, 1895, pl. 3.)

gluing its enemy in its sticky, and "without doubt" venomous, spatula-like cerata.

Trinchése (*in* Risbec, 1928, p. 21) reported similar autotomous behaviour in *Caliphylla borgnini.* Cerata detached from individuals of this species thrash about and live for about 2 days. Such longevity was explained by Trinchése as having its source in the fact that each ceras contained portions of all of the organ systems of the body, with the exception of that of reproduction. Besides other details, the digestive diverticulum was said to be rich in *"substances alimentaires,"* which presumably would be an energy source permitting both violent activity and relatively long life of the detached members. Risbec, however, believed it more reasonable that such muscular movements simply reflect continuation of the normal activity of the cerata, which, in life, are very motile and serve in locomotion.

Nudibranchia

There are two major anatomical regions known to be autotomous in the Nudibranchia. The first involves the mantle margins, irregular pieces of which may be thrown off by several species of the Dorididae (see, for example, Risbec, 1928; here fig. 3, D). Eliot (1899) made the remarkable observation that, when handled, *Discodoris fragilis* may leave behind it a complete ring of mantle more than a quarter of an inch wide, while the central part crawls away, apparently none the worse for the loss. The process of autotomy is not rapid, and would not protect the nudibranch against a fish or any quick-moving predator, but might enable it to escape the attacks of a carnivorous mollusk, according to Eliot. Similar observations were made by Haefelfinger (1961, p. 334) on *Peltodoris atromaculata,* in which the phenomenon was only seldom seen and then only under extreme conditions, for example, in the presence of rotting food or when the oxygen or circulation systems of the aquarium were shut off for a long time. He noted that regeneration occurred and that this power seemed to be rather great.

Allan (1932a, p. 88) characterized the genus *Discodoris* Bergh, 1877, as having the ability to discard a portion or the whole of the mantle margin when the animals are handled. Pruvot-Fol (1934, p. 221) used this feature to support a strong presumption that *D. maculosa* (Cuvier, 1804) was in this and not in some other genus, and Allan (1959, p. 222) held that the entire subfamily Discodoridinae was so characterized. However, mantle autotomy has yet to be observed in the Californian species *Discodoris heathi* MacFarland, 1905. From the Synopsis one can determine that this ability is not restricted to *Discodoris* alone, for Bergh (1891, p. 122) stated that with strong irritation *Argus* and *Peltodoris,* as well as *Discodoris,* will throw off pieces of the mantle margins. Mantle autotomy in *Kentrodoris inframaculata* was thought by Risbec (1928, p. 22) to be aided by liquifaction of the tis-

sues as well as by endogenous spicules which, arranged in groups perpendicular to the body surface, form zones of weakness.

The cerata, which project from the dorsal body surface, comprise the second major anatomical structure frequently autotomized by nudibranchs (fig. 4). Such cerata have been said to be "deciduous" or "caducous." Those of *Melibe* were observed to be cast off when the animals were placed in formaldehyde (Heath, 1917, p. 139) or were slightly disturbed (Pease, 1860, *in* Ostergaard, 1955, p. 135). *Propemelibe mirifica,* a very large form, was observed by Allan (1932b) to cast off cerata that showed signs of life for several days, curling up the edges when touched and exhibiting general movement. Allan believed it probable that the vivid coloring and sickly-sweet smell of the autotomized cerata were protective qualities. New cerata were regenerated and grew very rapidly to some inches in a few days (Allan, 1959). Parona (1891) brought about autotomy in *Tethys leporina* (fig. 4, B) by striking the animal, which then shed six of the 16 cerata. In contrast with *Propemelibe,* it required 2 months for the cerata of *Tethys* to regenerate to about one-third their normal length.

In the autotomous cerata of *Doto coronata* (fig. 4, E) a flat layer or zone of intensely staining connective tissue was noted by Hecht (1895, p. 609). This layer is located near the point of insertion of the ceras upon the body and is interrupted only by the passage of the digestive diverticulum. It extends, presumably as a septum, from one side of the ceras to the other, clearly stopping against the layer of longitudinal muscle fibers underlying the epithelium (fig. 3, E, m). Hecht believed that this zone performs some unknown role, perhaps forming a point of least resistance, preparing an easy release of the ceras; perhaps acting as a closing plug after the autotomy; perhaps comprising a layer of embryonic tissue ready to assure the regeneration of the ceras; or perhaps performing more than one of these roles. Hecht observed (p. 606) that new cerata were regenerated very quickly in *Doto,* and he concluded that autotomy was a means of defense.

Baba and Hamatani (1965, p. 105) mentioned that the cerata easily fall off the body of *Sakuraeolis enosimensis.* In their plate 8, figure 3, they illustrated a longitudinal section of a ceras, the figure caption indicating a sphincter muscle and a septum at the base of this structure. These features were not discussed in the text, but the septum may bear some resemblance to the peculiarities described by Hecht for *Doto coronata.*

Hecht (1895) introduced the term "adhesive autotomy" to describe the condition whereby released cerata of *Zephyrina mucronifera* (fig. 4, G) adhere by their bases to the object that touched them. He described (p. 606) the cerata of this species as having well developed longitudinal muscle fibers, which, upon contraction, pull back the zone of implantation of a ceras and constrict the opening of the digestive diverticulum within it. At the

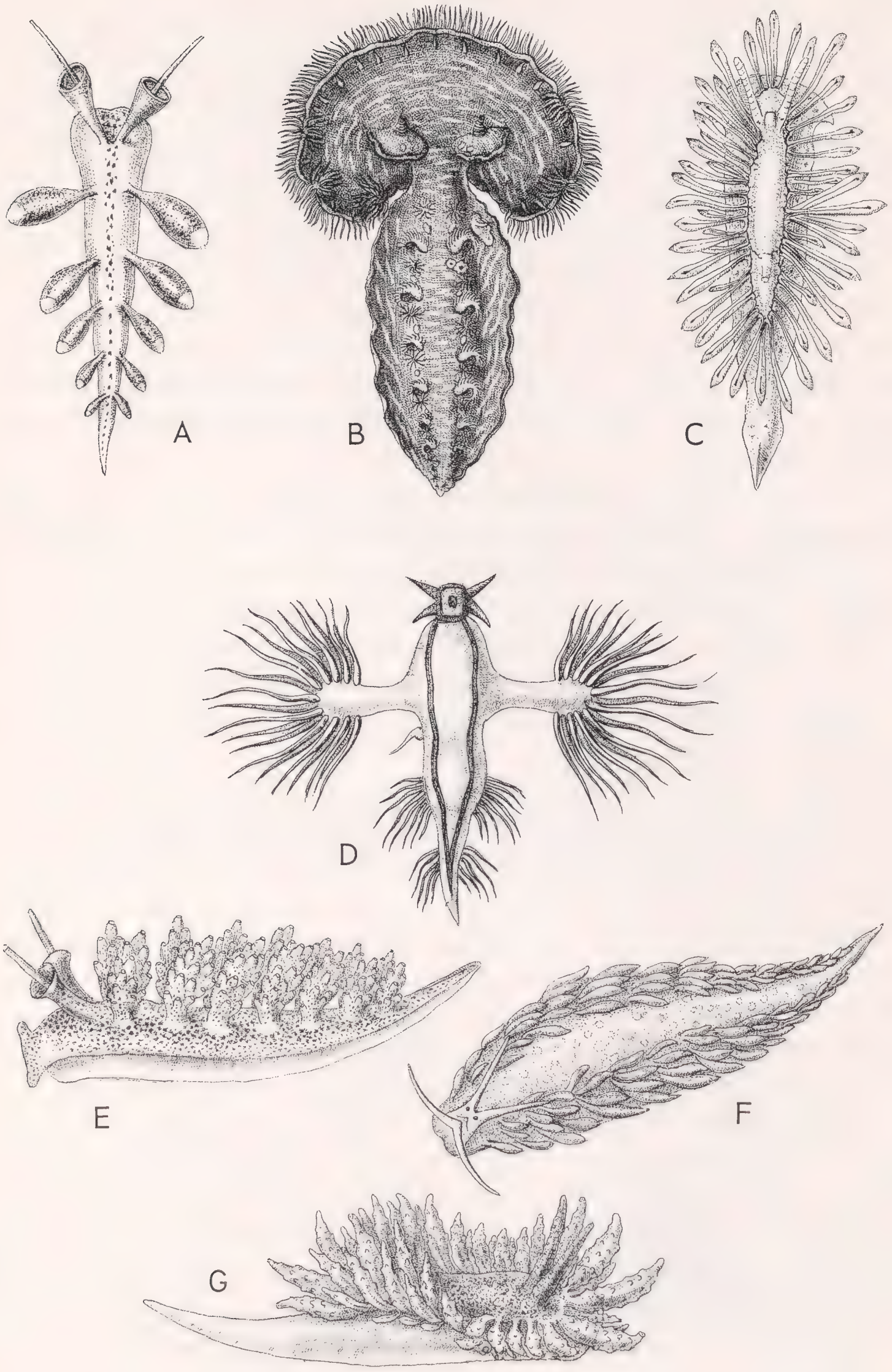

FIGURE 4. Various nudibranchs representing genera reported to autotomize the cerata. **A**, *Doto affinis*; **B**, *Tethys leporina*; **C**, *Janolus cristatus*; **D**, *Glaucus pacificus*; **E**, *Doto coronata*; **F**, *Aeolidia papillosa*; and **G**, *Zephyrina mucronifera*. (From Adams and Adams, 1858, pl. 65.)

same time, the epithelium in that region forms a sort of [suction?] cup, which, to Hecht, explained why the cerata so strongly adhere by their bases, even to very smooth objects. Risbec (1928, p. 20), however, concluded that the cerata secrete an adhesive and perhaps venomous fluid. (See also the note on *Caliphylla australis*, p. 9). In all likelihood Hecht overlooked the presence of one or more sphincter muscles on the proximal side of the abscission, for the conditions he described, and also those noted by Edmunds (1966, p. 76) in *Stiliger vanellus*, do not seem to be the results of contraction of longitudinal muscles, which would shorten the ceras but not necessarily constrict it or pull it away from the body. In *Dirona albolineata*, for example, MacFarland (1912) observed such sphincter muscles about large blood vessels at the base of each ceras. He thought that by contraction of the sphincters the lumina of the vessels would be closed should the ceras be accidentally lost.

Graham (1938) investigated the alimentary canals of the aeolids *Aeolidia papillosa* (fig. 4, F), *Cratena glotensis*, *Eolidina (=Aeolidiella) alderi*, and *Facelina drummondi*. Unfortunately, where he writes of the autotomous cerata (p. 303) he does not note which of these species formed the basis for his observations. Perhaps his generalizations apply to all four, but because of the lapsus I have not included these aeolids in the synopsis.

Graham observed that each ceras has at its base a sphincter muscle that not only allows the ceras to be easily shed, but that also closes the opening left by the autotomy. As also noted by Risbec (1928), the autotomized cerata leave no trace upon the body, and both Risbec and Graham remarked on the independent movement or writhing of autotomized cerata, an activity thought to divert the attention of a presumed predator that initiated the autotomy. In *Aeolidia poindimiei*, Risbec (p. 246) observed that at the time of separation the closed end of the digestive diverticulum forms a swollen vesicle within the released ceras, while at the zone of separation there is found a tissue comprised of cells regularly disposed in palisades. No suggestion as to function was put forth to account for these conditions.

Haefelfinger and Stamm (1959, p. 422) reported that the cerata of *Limenandra nodosa* easily fall off and that they are regenerated, while Macnae (1954, p. 42) observed that an almost rectangular scar was left following ceratal autotomy in the pelagic nudibranch *Glaucus atlanticus*. In this scar could be seen the narrow passage for the digestive diverticulum. Perhaps the specimens used by Macnae were dead or preserved, thus constriction of the wound had not taken place. A related species, *G. pacificus*, is illustrated in figure 4, D.

Forster very early reported that *Glaucus* readily detached the long tail-end of its foot, but Bergh (1884, p. 14), who referred to Forster's statement, only rarely saw an individual that was without that member. The statement by Adams and Adams (1858, p. 436) that some nudibranchs have the

power to spontaneously throw off the hind part of the foot when the animal is irritated may refer to *Glaucus*.

Graham dealt at length with the presence of nematocysts in the tips of aeolidean cerata. These nematocysts, derived from the coelenterate food of the nudibranchs and retained undischarged within special cnidosacs, form a defense mechanism closely associated with autotomy in that family. Similarly, secretions, coloration, behavior and other attributes of opisthobranchs are significant as defense mechanisms (Thompson, 1960; Edmunds, 1966).

Pulmonata

Cockerell (1890a), in his description of the land slug *Prophysaon coeruleum*, was probably the first to observe the effects of autotomy in the genus. He stated that "In one specimen the posterior portion of the foot was eaten off at the end." Later in the same year he recorded in a footnote that Hemphill had actually observed the autotomy (Cockerell, 1890b). Referring to the same footnote, Raymond (1890) noted that autotomy of the foot does not occur in young specimens. Binney (1892) recorded another observation made by Hemphill who found that the severed piece in what he called *Phenacarion* possessed as much vitality as the animal proper.

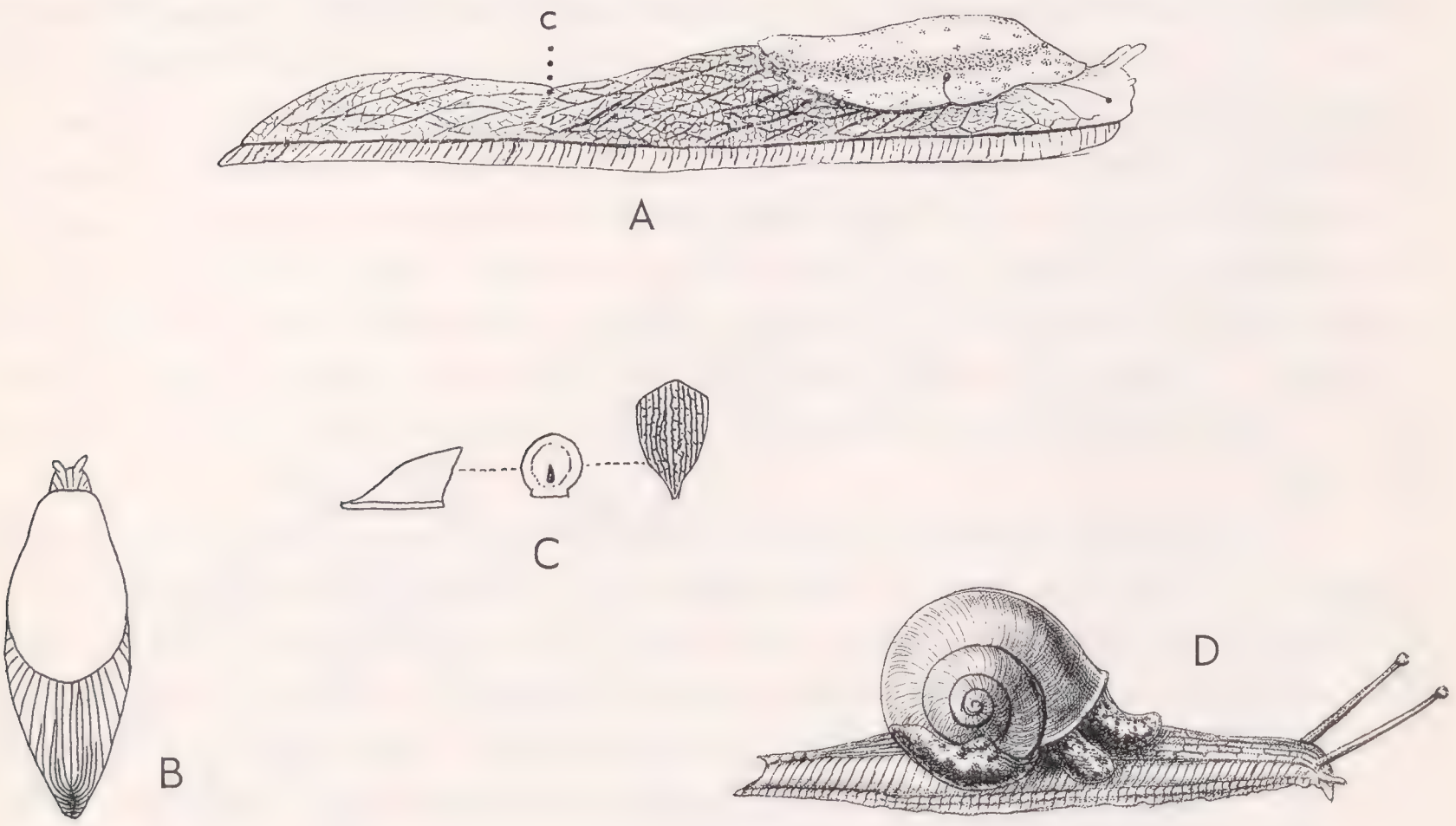

FIGURE 5. **A**, *Prophysaon foliolatum*. Animal from the right side showing constriction (**c**) at which autotomy occurs. **B**, *P. coeruleum*, dorsal aspect of preserved specimen from which posterior portion of foot has autotomized. **C**, Three views of autotomized piece from specimen shown in B. **D**, *Helicarion viridis*, animal from the right side. (**A-C**, from Pilsbry, 1948; **D**, from Adams and Adams, 1858, after Quoy and Gaimard, 1833.)

What little is known about autotomy in these slugs may be found in the volume by Pilsbry (1948, pp. 677, 680). He described *Prophysaon* as a genus in which the tail shows an oblique constriction at the posterior third to sixth of the animal's length (fig. 5, A-C), the constriction marking the site where self-amputation occurs, even in one's hand. Significantly, he observed that the body cavity does not extend beyond the constriction, and he predicted that the tail would be found to regenerate. However, specimens of *P. andersoni* that were pinched, shaken, dropped, pricked, and put in preservative all failed to autotomize, so that Ingram (1948) concluded that not all specimens had the ability. This species was illustrated by Lovett and Black (1920), their painting showing the constriction described as characteristic for the genus.

In 1943, Gregg recorded autotomy of the posterior third of the foot in *Limax marginatus* from southern California. The same author (Gregg, 1944) coined the term "auto-urotomy" for this ability and observed complete severence of the last quarter of the foot after his specimens had been placed in a drowning jar.

In relating his observations on snails of the genus *Helicarion* (fig. 5, D), Semper (1881, p. 375) stated that "Every species that I personally examined possessed the singular property...of shedding their tail when they are seized somewhat roughly, at a little way behind the shell. This they do by whisking the tail up and down with extraordinary rapidity, almost convulsively, till it drops off ..." Semper hypothesized that this behavior functions as protection against birds and reptiles, and he referred to similar observations made by Guilding for snails of the genus *Stenopus*. *Helicarion* is characterized by a shell too small to fully accommodate the body, and the tail-whisking behavior may function by attracting attention away from the snail proper. It may aid the breaking process should the foot be seized, and, perhaps, it may supply sufficient force to throw the body of the captured snail some distance away from the predator, which would be left with the tail only.

Pfeiffer and Gundlach (1861) recorded that *Pleurodonte (Polydontes) imperator, P. apollo,* and *P. crassilabris* are similarly able to throw off the hind part of the foot. Gundlach, who made the observations in Cuba, noted that the "tail" was very swollen in some individuals, absent in others, and that seizure always brought about autotomy at the same place. Four autotomized "tails" were found to live 54 hours following their release.

Snails of the genus *Nanina* (now *Xesta*) are included in the same family as *Stenopus*. Benson (1835) observed that in *Nanina* "There is an orifice under the posterior caudiform appendage in the form of an isosceles triangle with the apex downwards, whence a thick greenish juice exudes when the animal is handled or irritated, the caudal appendage being turned up and protruded towards the exciting object." While autotomy does not oc-

cur, the behavior of these snails aids in establishing that land gastropods do experience attacks from predators as yet unknown and that the posterior end is an advantageous location for glandular or autotomous protective devices. That snails may be eaten by reptiles is indicated by Wolcott's (1924) analyses of stomach contents of Puerto Rican lizards, of which six species yielded snails unfortunately not identified. Whether autotomous species are attacked remains speculative.

Scaphopoda

The only original record that I have seen to autotomy in the Scaphopoda is that of Lacaze-Duthiers (1856, p. 381). He found that when the aquarium water in which the animals were kept was changed, the mollusks would reject the captacular bundles (fig. 6). The filamentous captacula, which are extensile and ciliated feeding structures, are easily regenerated, according to Pelseneer (1906, p. 199). These filaments extend from two leaf-shaped shields of tissue, the medial captacula on each shield being short and immovable, while lateral ones grade into longer mobile filaments. Riggenbach (1903, p. 817) suggested that as new buds appear, older filaments are pushed laterally and, eventually, are entirely released from the body. Under normal conditions, probably only the outer filaments would be lost, newer ones appearing medially to replace them. Thus, as more fully described in the discussion, this would be a serial replacement rather than a true regeneration.

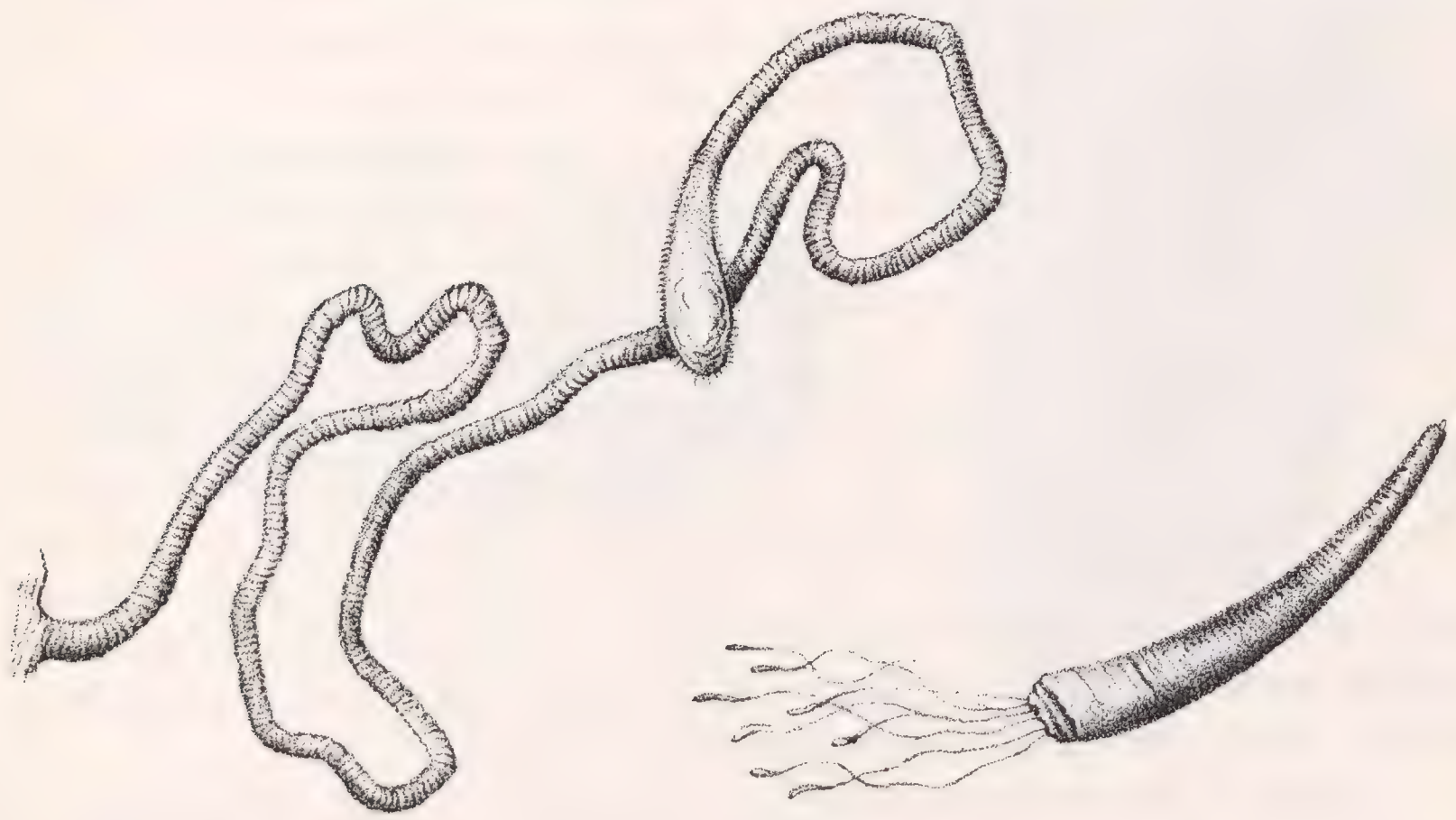

FIGURE 6. *Dentalium vulgare*. A single captacular filament much enlarged, and the animal from the left side showing shell and extended captacula. (From Lacaze-Duthiers, 1856.)

In view of how little is known of the conditions under which the captacula are normally lost, inclusion of their release as an autotomous act is speculative.

Figure 7. *Lima dehiscens*. Animal from the right side showing extended mantle tentacles. (Photo by A. G. Smith.)

BIVALVIA

Pectinacea

Gilchrist (1895, in Gilmour, 1963) noted the stickiness of the mantle tentacles of *Lima* (fig. 7) and that these were capable of autotomy, probably as a defense mechanism. Structural complexities of the tentacles of *Lima hians* were well described by Gilmour (1963). Each tentacle has along its external surface a large number of mucous gland cells arranged in rings, which give the tentacles of this genus their characteristic knobby appearance. Secretions from these cells are released upon stimulation and cause the tentacles to be tenaciously adherent. While the mucus is non-acid, Gilmour did not exclude the possible presence of an irritant substance. Within the tentacle there is a longitudinal hemocoelic canal divided at irregular intervals by muscular septa, each of which is pierced by a sphincter-bound pore. A stout, pierced septum is also located at the base of the tentacle.

There are no circular muscles within the tentacle, and when autotomy takes place it is brought about by contraction of radial muscles in a septum, at which separation occurs. Closure of the sphincter muscle accompanies autotomy, thus sealing the broken end of the tentacle.

Crabs, to which limas had been presented as food by Gilmour, appeared to be irritated by the sticky, autotomized tentacles and made vigorous attempts to free themselves from them. Gilmour concluded that secretion of mucus in conjunction with autotomy may serve a defensive function.

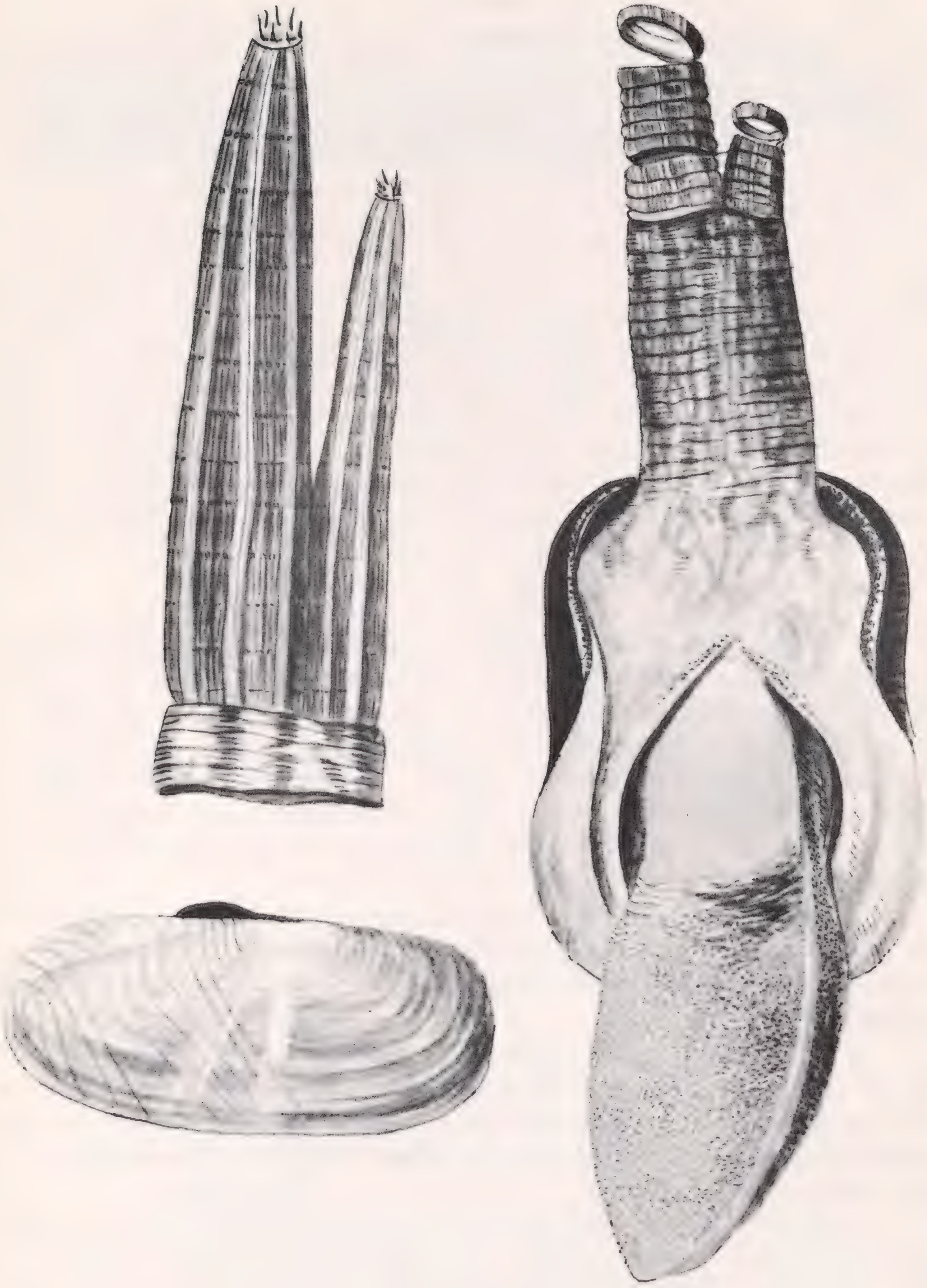

FIGURE 8. *Solecurtus strigillatus*. Aspect of extended siphons, the animal autotomizing the ends of the siphons, and side view of one valve. (From Poli, 1791, pl. 12.)

Tellinacea

Regarding *Solecurtus coarctatus*, Forbes and Hanley (1853, p. 262) reported that they had observed the annulated siphons to voluntarily break into fragments in the manner of the Mediterranean *S. strigillatus* (fig. 8). Rawitz (1892, p. 109 and following) observed the siphons of the latter species to be longitudinally striped. Of the stripes lacking pigment there are major and minor kinds. Mechanical stimulation of the major stripes resulted in siphonal contraction, while irritation of other parts of the siphons did not elicit a response unless the stimulus was strong enough to cause injury. With contraction of the siphons, characteristic ring-shaped constrictions appear along their length, as shown in figure 8. With excessive agitation, one or more ring-shaped segments of the siphons can be autotomized, a similar result being obtained when the animal is placed in preservative. Similarly, Atkins (1937, p. 392) observed that portions of the distal, unfused portions of the siphons of *Solecurtus scopula* were thrown off by sudden violent muscular contractions when the animals were rapidly removed from the water or when roughly handled.

Solenacea

Oehlert (1886) and Cooke (1895) mentioned that roughly handled solens may, by violent muscular contraction, throw off portions of the foot. Since Oehlert did not refer to the species to which his observations pertained, it is not known whether this peculiar activity is widespread or applies only to *S. siliqua*, the species given by Cooke. Because of possible rupture of blood sinuses, such autotomy probably would inhibit rapid subsurface escape movements. Needless to say, the process seems *a priori* disadvantageous.

Several species of *Solen* bear autotomous siphons, which, unlike those of *Solecurtus*, are mutually fused for their entire length. The siphons are characteristically annulated, as illustrated by Poli (1791), here shown in figure 9, A.

Fischer (1887, p. 101) stated that he often found loose annulations on the surface of the substratum near the burrows of *Solen marginatus*. In this instance disturbance created by the collector as he walked near the burrow may have been the stimulus for the autotomy. While Ricketts and

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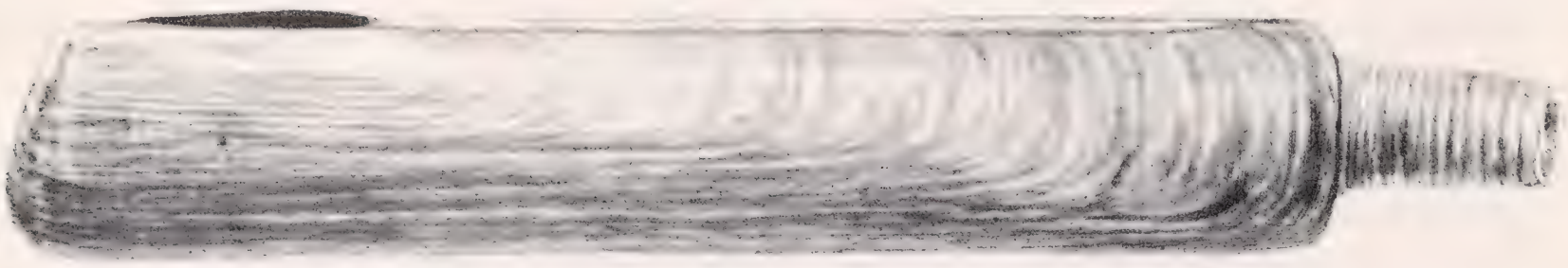
Figure 9. **A**, *Solen siliqua*, showing annulated siphons. **B**, *S. fonesi*, showing extended foot and annulated siphons. **C**, *S. fonesi*, showing rings of tentacles on the siphons. **D**, *S. fonesi*, a cast-off section of the siphons, end view. **E**, *S. sicarius*, normal siphonal tips, end view; exhalant aperture (**ea**), flaring membrane (**fm**), inhalant aperture (**ia**). **F**, *S. sicarius*, end view of siphons immediately after removal of distal-most section; blood channel in siphonal septum (**bc**), severed nerve bundle indicated by dotted circle (**nb**), buds of incipient siphonal tentacles (**tb**). (**A**, from Poli, 1791; **B-D**, from Annandale, 1916.)



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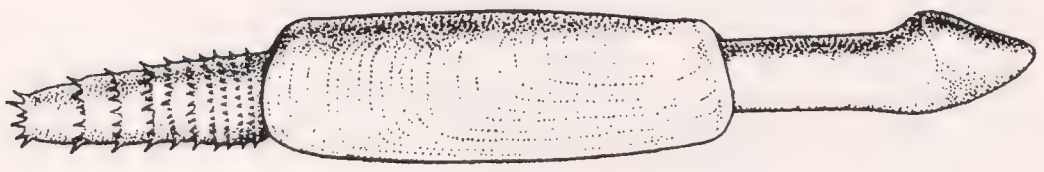

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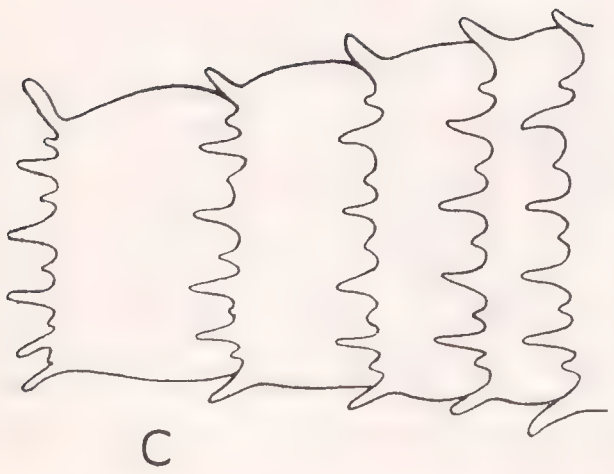

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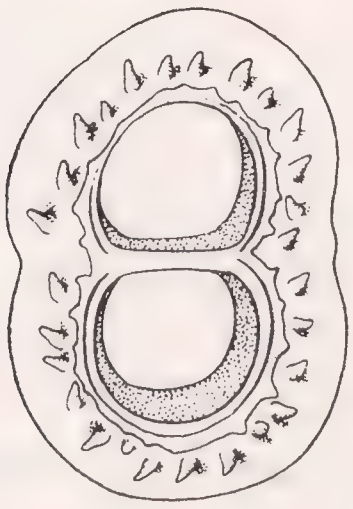

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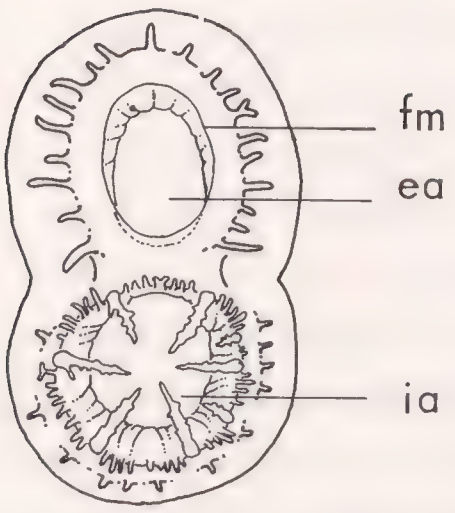

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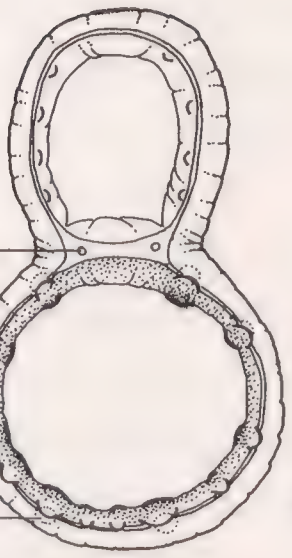


F

Calvin (1952) somewhat facetiously suggested that the ability of siphonal autotomy may be an adaptation to predation by birds, Carlisle and his coworkers (1960, p. 49) made the observation that in southern Californian waters the barred surfperch eats *Solen rosaceous*. Orcutt (1950) found many siphonal tips among the stomach contents of the starry flounder. These siphons were identified as those of *Siliqua patula* and of other species not possessing autotomous siphons, but since this flounder also frequents areas where *Solen* is found, that these clams are likewise preyed upon is probable (Orcutt, personal communication). In Great Britain, Smith (in Atkins, 1937, p. 393) directly observed autotomy in *Solen marginatus* when a medium-sized plaice nibbled at the siphonal tips. That predatory fish comprised an ecological factor leading to the evolution of autotomous siphons in the Solenidae seems fairly well established, in my opinion. Under laboratory conditions, Faussek (1897. in Riggenbach, 1903, p. 820) initiated autotomy in *S. marginatus* by electrical stimulation of the visceral ganglia.

A specimen of *Solen fonesi* was reported by Bloomer (1907) to have part of the siphon "broken off," and Annandale (1916, p. 355) also noted autotomy of the segmented siphons in this species. He observed that there is a ring of minute tentacles around the distal end of each segment of the siphons and thought that these tentacles probably have a sensory function, "...the new tip as well equipped as the old." Annandale's figure 5 (here fig. 9, B-D) shows these siphons, the rings of tentacles about the sections being on the external surfaces. Autotomy in this species is the result of contraction of radial muscles interconnecting the inner and outer epithelia of the siphons and found only at the junctures between sections (Ghosh, 1916, p. 370).

Solen rosaceus will autotomize its siphons at annular constrictions when the animal is roughly handled or if the aquarium water becomes stale (Ricketts and Calvin, 1952, p. 241; Pohlo, 1963, p. 100). Pohlo observed that "The siphons are annulated for their entire length, and each annulation has a fully developed set of siphonal tentacles. When the siphons are autotomized,...a new set of tentacles is already formed and apparently ready to function." Strikingly, the sets of tentacles are on the inside walls of the siphonal tubes rather than on the outside as in *S. fonesi.*

Ricketts and Calvin (p. 252) noted siphonal autotomy in *Solen sicarius*, a species studied by the present writer at the Friday Harbor Laboratories, Washington. *Solen sicarius*, like other autotomous members of the genus, has annulated siphons. Friday Harbor specimens 55 mm., 87 mm., and 90 mm. in greatest dimension bore six, seven, and eight siphonal sections respectively, thus suggesting a direct relationship of size and number of annulae present. The normal tips of the siphons are illustrated in figure 9E. About the inhalant aperture *(ia)* is a series of, usually, six large lobed and serrated tentacles that bend inwardly over the aperture. These are here termed

the primary tentacles. Lying between the primary tentacles are much smaller secondary tentacles, which bend outwardly. An incomplete ring of simple tentacles lies proximal to the primary and secondary tentacles.

The exhalant aperture *(ea)* is bordered by a thin flaring membrane *(fm)* raised above an incomplete ring of simple tentacles. Irregularly placed tentacles may exist between the flaring membrane and the ring of tentacles.

When the distal section was pulled with forceps, it was easily separated along a clearly marked constriction, the separation resembling an ungluing rather than a rupture of tissues (see note on *Harpa*, p. 6). Longitudinal nerve cords traversing the zone of weakness seemed only slightly more tenacious than the rest of the tissue. The distal end of the former penultimate siphonal section is shown in figure 9 F. Upon separation at the annular constriction, the inner and outer surfaces about the inhalant and exhalant canals contracted. This contraction was not great enough to completely cover the raw tissue lying between the surfaces, especially the tissue of the siphonal septum, which contains two conspicuous, although constricted, blood channels *(bc)*. On the distal margin of the more heavily pigmented inner surface of the inhalant siphon one could observe a ring of swellings or papillae *(tb)*, six of which lay adjacent to the ends of the six severed nerve bundles *(nb)*. Similar, although smaller raised areas were present on the inner surface of the exhalant siphon. Based on eight specimens from which one to three siphonal sections had been artificially removed, the gross process of regeneration proceeded as follows:

On day 2, that is, on the day following that on which the separation was made, the inner and outer surfaces of the siphons had fused over the exposed tissue. The line of fusion was clearly indicated by differences in pigmentation, the inner surface being darker. The tissue covering the siphonal septum was heavily pigmented, and was apparently derived from the inner surface of the inhalant siphon. Also on this day the small swellings of the inhalant aperture consisted not only of inner layer, but of outer layer also, as indicated by regional differences in pigmentation.

On day 3, the distal end of the siphons had grown by about 0.4 mm., as suggested by a difference in pigmentation. The largest swellings of the inhalant aperture were about 0.2 to 0.3 mm. from base to tip in the specimens from which 3 sections had been removed, about 0.4 mm. in that lacking 2 sections, and about 0.5 mm. in the two missing 1 section. Small swellings were visible just proximal to the edge of the exhalant aperture.

On day 4, swellings suggesting incipient secondary tentacles were visible on the outer surface of the inhalant aperture of one specimen. The largest swellings, now recognizable as prospective primary tentacles, ranged from 0.3 to 0.75 mm. long, the specimens lacking only one section still having the larger tentacles.

On day 5, the flaring membrane about the exhalant opening was distinctly present in all but one specimen from which 3 sections had been removed. Tentacle buds about the flaring membrane were distinct, those of two specimens having grown to 0.4 mm. long.

On day 6, the primary tentacles of the new siphonal tip had become 0.5 mm. to 1.2 mm. long; the secondary tentacles measured up to 0.3 mm. long, and those about the exhalant aperture were 0.2 mm. to 0.5 mm. long.

While the siphonal apertures closed upon stimulation, the secondary tentacles tended to bend outwardly, and the larger, primary tentacles bent inwardly over the closed aperture.

By day 7, some of the longest primary tentacles had small serrations along their sides and were 0.7 mm. to 1.5 mm. long; secondary tentacles were only up to 0.4 mm. long. Tentacles about the exhalant aperture ranged from 0.25 mm. to 0.6 mm. long.

Although these specimens were not followed beyond 7 days, it was apparent that the small pigmented buds present on the border of every section of the siphons represented prospective tentacles whose development was arrested until more distal sections had been removed, thus curiously resembling the condition in plants in which lateral stem buds may remain inactive until the terminal bud is removed. The condition in *Solen sicarius* is quite different from that in *S. rosaceus* in which proximal tentacular development does not appear to be inhibited, fully grown sets being present on subterminal sections.

CEPHALOPODA

All reported instances that I have seen of autotomy in the Cephalopoda are limited to the order Octopoda, and in this order to the Octopodacea (Octopodidae) and the Argonautacea (Tremoctopodidae, Ocythoidae, and Argonautidae).

Octopodacea

While Lane (1960) reported that some octopuses will voluntarily break off an arm when it is held, a most remarkable instance of octopdian autotomy was observed by Straughan (1957). In trying to transfer an unnamed species of octopus from a jar, Straughan proded the specimen with a rod. The octopus "....struck out viciously at the rod, somehow detaching one of his arms in the process, and before I realized that had happened, one of the arms came crawling out of the jug and slithered up my arm almost to the shoulder...." Four arms were eventually so detached. If this independent brachial activity occurs in nature, its defensive qualities can hardly be doubted.

Lange (1920), in studying regeneration of the arms of cephalopods, noted in the octopus that there was an absence of bleeding from the cut

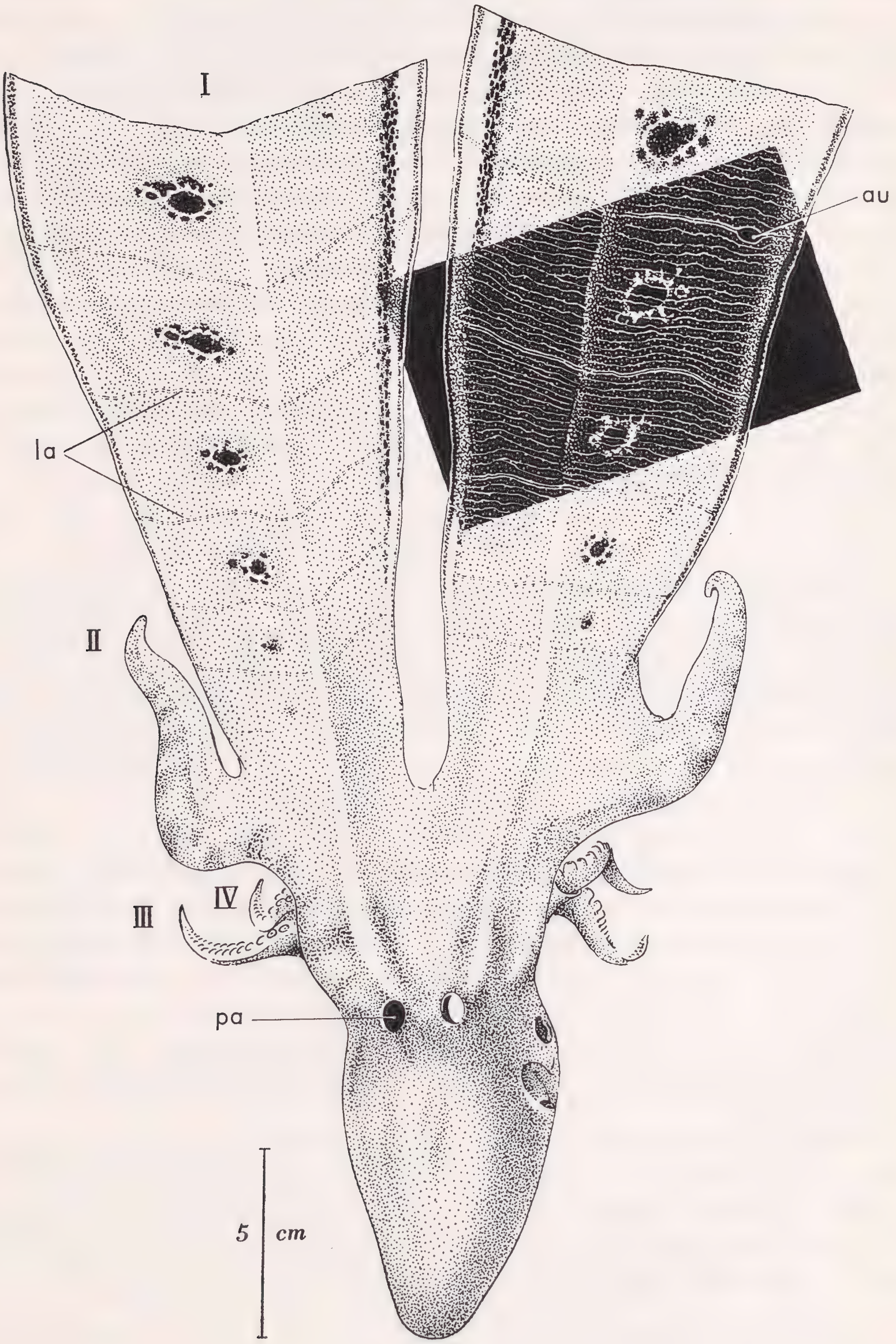
surfaces of artificially amputated arms. She stated that such retention of blood is probably associated with the ability to autotomize distal portions of the arms. She noted no specialized region for the point of autotomy, which often, but not always occurred four-fifths of the distance from the arm tip. Immediately after removal of the arm tip, the external rim of the wound contracted spasmodically, the central musculature and the axial nerve remaining unprotected. Delayed bleeding, however, occurred 5 or 6 hours following the operation, the clotted blood forming a preliminary covering for the wound prior to commencement of regeneration. It seems to the present writer that delay of bleeding might serve in aiding escape from predators that employ olfactory stimuli to track down prey. That such an adaptation might prove useful is suggested by the statement by Robson (1929, p. 21) that octopods are often found with portions of the arms missing, even to the extent that all of them are reduced to stumps. Attacks by enemies, autotomy, and autophagy were given as possible explanations.

Argonautacea

Among the pelagic Argonautacea there are two kinds of autotomy. The first involves the pair of dorsal arms of *Tremoctopus*, as well described by Portmann (1952). In the females of *Tremoctopus violaceus* these arms are greatly elongated and flattened (fig. 10). Each is characterized by a longitudinal row of brilliant red spots or ocelli, each ocellus being bordered by dazzling white. The dorsal surface of the arm is gray to reddish-brown, and the ventral surface passes from brilliant orange to cherry red and to purple through violet or deep brown. In addition there are flashes of irridescent green and metallic gold. Midway between any two ocelli there is a transverse line that marks a zone of weakness (fig. 10, 1a). These zones of weakness divide the arms into segments that the animal is capable of throwing off. Upon release from the arm, one segment had increased its span from 78 mm. to 198 mm., thus confirming earlier observations that segments are held under partial contraction as long as they remain on the body. New segments seem to be formed at the base of the arms, as indicated by the incipient sections there.

Arranged transversely within the tissues of these arms are numerous cords, each of which is composed of a muscle bundle spirally wrapped with a dense envelope of connective tissue. The zones at which autotomy occurs are located where two transverse bundles are adjacent to one another. Rupture always occurs along the thin part between two such bundles.

Portmann referred to the observations of an earlier investigator who noted that when a female of *Tremoctopus* was swimming peacefully, the dorsal arms were rolled up by the ventral side. When irritated, the animal unfurled its arms and swam rapidly backwards, thus trailing the brightly col-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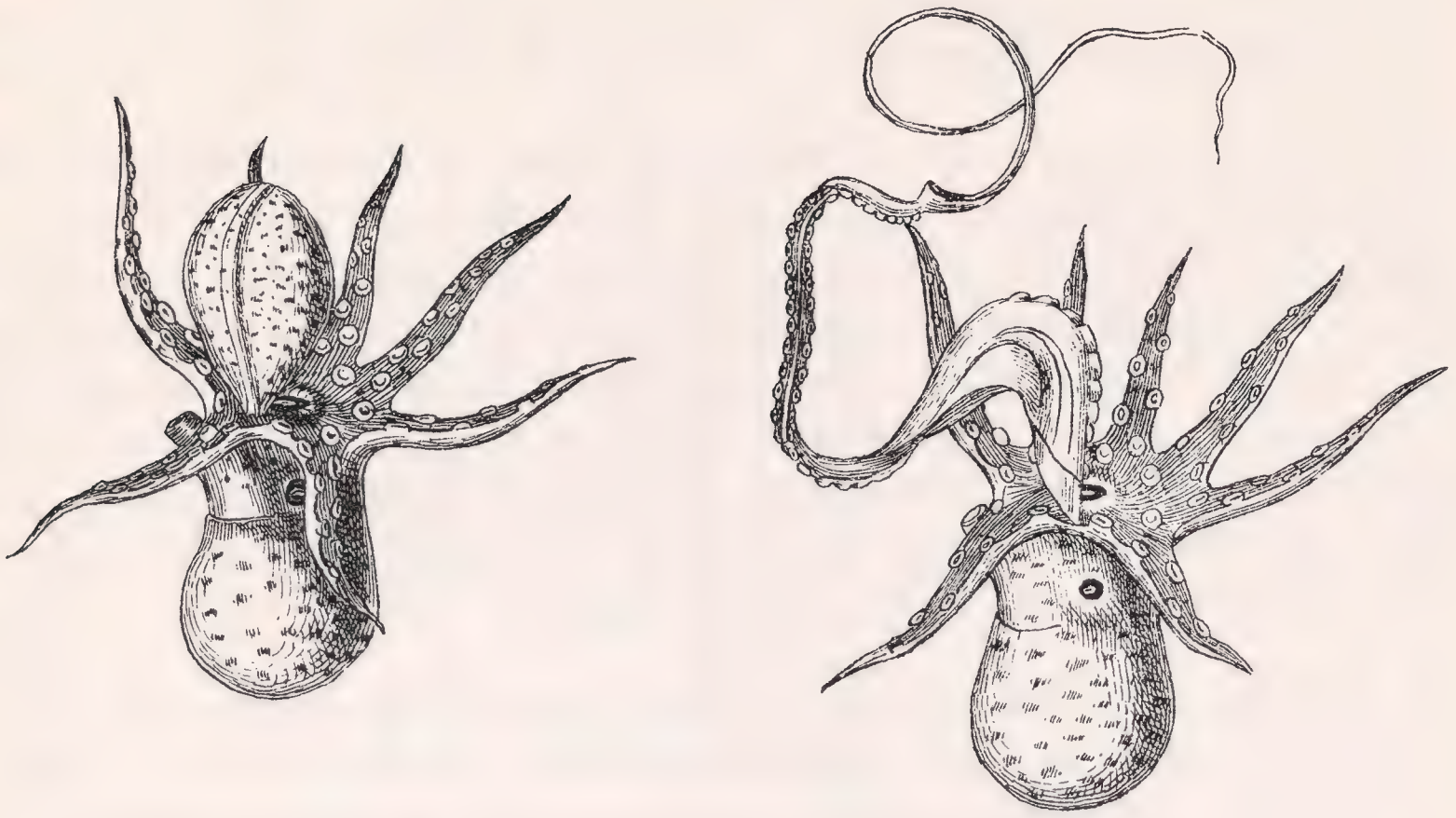

FIGURE 11. *Argonauta argo.* Male specimen, showing hectocotylus within its sac, and with the hectocotylus extended. (From Tryon, 1882, pl. 16.)

ored structures behind it. Although Portmann cautiously avoided speculation on the function of this behavior, that it is a defensive mechanism seems more than likely (Young, 1959, p. 410). The sudden appearance of the bright colors may serve to startle a predator, and, if a segment of the arm is autotomized, its rapid increase in size may aid total escape by detracting the attention of the pursuing animal away from the octopod.

In the families Tremoctopodidae, Ocythoidae, and Argonautidae the males, which may be about one-twentieth the length of the females, are provided with an autotomous arm, elongated and otherwise modified as an organ of copulation. During its development this organ, known as the hectocotylus, is coiled up within a sac of tissue (fig. 11). At some unknown time prior to copulation the sac ruptures and allows the contained arm to extend. With this arm a packet of sperm is transferred to the mantle cavity of the female, the arm somehow detaching and remaining within that space. In the Tremoctopodidae and Ocythoidae, the third right arm is specialized in this way, while in the Argonautidae the hectocotylus is the third left arm.

Hoyle (1908, p. 521) remarked that "...it is not known for certain whether the fertilizing arm is deposited by the male in the mantle-cavity of the

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FIGURE 10. *Tremoctopus violaceus.* Female specimen in dorsal aspect; arms (I-IV), beginning of autotomy between two sections of one of the dorsal arms (au), lines indicating zones of weakness at which autotomy occurs (la), dorsal aquiferous pores (pa). (From Portmann, 1952.)

female (as I think is most probable), or whether (as stated by some writers) the arm breaks off when mature and finds its own way to its destination.

This much is certain, that for some time after its detachment it possesses the power of independent movement." More recently, Young (1959, p. 409) stated that "The male argonaut is a minute creature, which develops little beyond the larval stage except for the production of an enormous sexual arm. This is introduced into the mantle cavity of the female and there broken off from the male, a process of autotomy... This takes place while the female is still young and the male arm, charged with spermatozoa, lives on within the female until she is mature and the eggs are ready for fertilization, though the details of this are not known."

Considering the size differences between the sexes, one possible function of an autotomous hectocotylus might be not only that of ensuring deposition of the spermatophore, but also that of ensuring escape of the minute male individual from the female; that is, the loss could be evasive in character. That the male might be endangered is suggested by Wells (1962, p. 35). He noted in *Octopus vulgaris* that copulation is conducted at a distance, and he indicated that the males possess certain anatomical features that may serve as signals inhibiting attack by the female, especially if the male is the smaller of the pair.

Wells also suggested (p. 36) that "...it is possible that cephalopods, in general, spawn only once and then die." If small male cephalopods are in danger from the females and if spawned males may soon expect to die, evolution in the minute males of the Argonautacea of a complicated autotomous capability that, under other circumstances would tend to prolong the life of the male, seems unlikely: there would have been no way for natural selection to operate in favor of escaped males, that is, in favor of males with the most efficiently autotomous hectocotyli. In this regard it may be noted that although regeneration of the hectocotylus was assumed by Steenstrup (1857, p. 107) and by Coe (1944, p. 94), reasonable doubt was expressed by Grimpe (1928). If this arm, once lost, is not regenerated, the implication is that any male can reproduce but a single time. Loss of the hectocotylus might thus be regarded as an ontogenetic loss perhaps broadly comparable to conditions reported in the pteropod *Herse columnella* (p. 9), although protandry is out of the question in the Cephalopoda (Coe, 1944, p. 94).

In view of the present paucity of knowledge, I feel free to suggest that male of Argonautacea might simply be eaten by the females, with only the sperm-charged hectocotylus remaining behind. Efficient autotomy of the hectocotylus would thus be advantageous to the species, if not to the male individuals, and provide some basis upon which natural selection could act.

SYNOPSIS OF AUTOTOMY IN THE MOLLUSCA

TAXONOMIC ARRANGEMENT PRIMARILY THAT OF THIELE, 1931, 1935

GENERIC NAMES USED BY THE PRINCIPAL REFERENCES ARE IN BRACKETS

GASTROPODA

PROSOBRANCHIA

FAMILY	GENERA	SPECIES	PART AUTOTOMIZED	PRINCIPAL REFERENCES
Trochidae	*Stomatella*	....	Posterior part of foot	Hedley (1902), Talmadge (personal communication)
		S. auricula	Posterior part of foot	Quoy and Gaimard (1834, p. 310)
	Stomatia	....	Posterior part of foot	Allan (1941)
	Gena	....	Posterior part of foot	Adams and Adams (1858), Hedley (1902)
		G. varia	Posterior part of foot	Fishelson and Qidron-Lazar (1966)
Calyptraeidae	*Calyptraea* [=*Haliotidea*]	....	Posterior part of foot	Pelseneer (1935)
Harpidae	*Harpa*	*H. ventricosa*	Posterior part of foot	Quoy and Gaimard (1832)

OPISTHOBRANCHIA

PTEROPODA

Cavoliniidae	*Herse* [=*Cuvierina*]	*H. columnella*	Male copulatory organs	Bonnevie (1916), Tesch (1946)

SACOGLOSSA

Oxynoidae	*Lobiger*	*L. serradifalci*	Posterior part of foot	Gonor (1961)
			Natatory appendages of foot	Riggenbach (1903, p. 824), Pelseneer (1935, p. 375)

Family	Genera	Species	Part autotomized	Principal references
		Sacoglossa *(Continued)*		
Caliphyllidae	*Caliphylla* [=*Phyllobranchus*]	*C. australis*	Cerata	Risbec (1928)
		C. borgnini	Cerata	Trinchése *in* Risbec (1928)
Stiligeridae	*Stiliger*	*S. fuscovittata*	Cerata	Lance (1962, p. 34)
		S. boodleae	Cerata	Baba (1949, p. 129)
		S. vanellus	Cerata	Edmunds (1966, p. 74)
		Nudibranchia		
Doridiidae	*Glossodoris* [=*Doris*]	*G. sordida* [1]	Mantle margin	Quoy and Gaimard (1832)
	Trippa	*T. ornata*	Mantle margin	Risbec (1928)
	Peltodoris	....	Mantle margin	Bergh (1891)
		P. atromaculata	Mantle margin	Haefelfinger (1961)
	Kentrodoris	*K. inframaculata*	Mantle margin	Risbec (1928)
		K. pseudofusca	Mantle margin	Risbec (1928)
	Discodoris	All species	Mantle margin	Bergh (1891), Allan (1932a, p. 88)
		D. maculosa	Mantle margin	Pruvot-Fol (1934)
		D. fragilis	Mantle margin	Eliot (1899)
		D. palma	Mantle margin	Allan (1959)

1. While Quoy and Gaimard (1832, p. 266) employed the name *Doris sordida,* Adams and Adams (1858, p. 50) list this species under *Actinodoris,* which Thiele (1931, p. 431) gives as a partial synonym for *Glossodoris.*

Family	Genera	Species	Part autotomized	Principal references
		NUDIBRANCHIA *(Continued)*		
	Asteronotus	*A. boholiensis*	Mantle margin	Risbec (1928)
	Argus [= *Platydoris*; *Doris*, in part]	....	Mantle margin	Bergh (1891)
		A. cruentus [2]	Mantle margin	Quoy and Gaimard (1832, p. 261)
Dironidae	*Dirona*	*D. picta*	Cerata	Dustin Chivers and David Powell (personal communication)
		D. albolineata	Cerata	Chivers and Powell, MacFarland (1912)
Tethyidae	*Melibe*	....	Cerata	Adams & Adams (1858)
		M. pilosa	Cerata	Pease (1860, *in* Ostergaard, 1955)
		M. leonina [= *Chioraera dalli*]	Cerata	Heath (1917)
	Propemelibe	*P. mirifica*	Cerata	Allan (1932b, 1959)
	Tethys	*T. leporina*	Cerata	Parona (1891)
Zephyrinidae	*Zehpyrina* [= *Proctonotus*]	*Z. mucronifera*	Cerata	Hecht (1895), Risbec (1928)
	Janolus [= *Janus*; *Antiopa*; *Antiopella*]	....	Cerata	Adams and Adams (1858, p. 65)
		J. aureocincta	Cerata	MacFarland (1966, p. 303)
		J. cristatus	Cerata	Riggenbach (1903, p. 822)

2. *Doris cruenta* Quoy and Gaimard, 1832, was placed in *Actinodoris* by Adams and Adams (1858) and in *Platydoris* by Risbec (1928, p. 75). Thiele (1931, p. 439) included *Platydoris* in the genus *Argus*, as shown above, but gives *Actinodoris* as a partial synonym for *Glossodoris*. Correct generic placement of this species is therefore questionable.

Family	Genera	Species	Part autotomized	Principal references
		Nudibranchia *(Continued)*		
Dotonidae	*Doto*	....	Cerata	Adams and Adams (1858, p. 65)
		D. columbiana	Cerata	MacFarland (1966, p. 289)
		D. coronata	Cerata	Hecht (1895)
		D. racemosa	Cerata	Risbec (1928, p. 19)
		D. varians	Cerata	MacFarland (1966, p. 289)
Flabellinidae	*Eubranchus*	*E. occidentalis*	Cerata	MacFarland (1966, p. 323)
Tergipedidae	*Embletonia*	*E. gracile*	Cerata	Risbec (1928, p. 271)
	Sakuraeolis	*S. enosimensis*	Cerata	Baba and Hamatani (1965)
Aeolidiidae	....	....	Cerata	Graham (1938)
	Hermissenda	*H. crassicornis*	Cerata	Mac Farland (1966, p. 360)
	Aeolidia [= *Eolis*]	*A. olivacea*	Cerata	Hecht (1895)
		A. exigua	Cerata	Hecht (1895)
		A. despecta	Cerata	Hecht (1895)
		A. trunca	Cerata	Risbec (1928)
		A. poindimiei	Cerata	Risbec (1928)
		A. obscura	Cerata	Risbec (1928)
		A. acinosa	Cerata	Risbec (1928)
		A. fragilis	Cerata	Risbec (1928)
		A. amoena	Cerata	Risbec (1928)
		A. [= "*Aeolis*"] *lineata*	Cerata	Riggenbach (1903, p. 822)
	Eolidina [= *Aeolidiella*]	*E. hulli*	Cerata	Risbec (1928)

Family	Genera	Species	Part autotomized	Principal references
		NUDIBRANCHIA *(Continued)*		
		E. embletonia	Cerata	Risbec (1928)
		E. gracilis	Cerata	Risbec (1928)
	Limenandra	*L. nodosa*	Cerata	Haefelfinger and Stamm (1958)
	Glaucus	....	Cerata	Allan (1941), Macnae (1954)
		....	Tail-end of foot	Forster, see Bergh (1884, p. 14)
		PULMONATA		
Arionidae	*Prophysaon*	All species	Posterior part of foot	Pilsbry (1948), Ingram (1948)
		P. coeruleum	Posterior part of foot	Cockerell (1890 a, b), Raymond (1890)
		P. [= *Phenacarion*] *foliolatum*	Posterior part of foot	Binney (1892)
Limacidae	*Limax*	*L. marginatus*	Posterior part of foot	Gregg (1943, 1944)
Ariophantidae	*Helicarion*	All species	Posterior part of foot	Semper (1881)
	Habroconus [= *Helix (Stenopus)*]	....	Posterior part of foot	Guilding *in* Semper (1881)
Pleurodontidae	*Pleurodonte (Polydontes)* [= *Helix (Polydontes)*]	*P. imperator*	Posterior part of foot	Pfeiffer and Gundlach (1861)
		P. apollo	Posterior part of foot	Pfeiffer and Gundlach (1861)
		P. crassilabris	Posterior part of foot	Pfeiffer and Gundlach (1861)

Family	Genera	Species	Part autotomized	Principal references
		SCAPHOPODA		
Dentaliidae	*Dentalium*	*D. vulgare*	Captacula	Lacaze-Duthiers (1856), Pelseneer (1906)
		BIVALVIA		
		Pectinacea		
Limidae	*Lima*	*L. hians*	Mantle tentacles	Gilchrist (1895, *in* Gilmour, 1963)
		Tellinacea		
Asaphidae	*Solecurtus*	*S. coarctatus*	Siphons	Forbes and Hanley (1853)
		S. strigillatus	Siphons	Rawitz (1892), Faussek (1897)
		S. scopula	Siphons	Atkins (1937)
		S. chamasolen	Siphons	Atkins (1937)
		S. gibbus	Siphons	Morse (1919)
		Solenacea		
Solenidae	*Solen*	*S. fonesi*	Siphons	Bloomer (1907), Annandale (1916)
		S. kempi	Siphons	Ghosh (1920)
		S. marginatus [= *S. vagina*]	Siphons	Pelseneer (1935), Atkins (1937), Rawitz (1892)
		S. rosaceus	Siphons	Ricketts and Calvin (1952), Pohlo (1963)
		S. sicarius	Siphons	Ricketts and Calvin (1952), personal observations
		S. siliqua	Tip of foot	Oehlert (1886), Cooke (1895)

FAMILY	GENERA	SPECIES	PART AUTOTOMIZED	PRINCIPAL REFERENCES
		CEPHALOPODA		
		OCTOPODACEA		
Octopodidae	*Octopus*	"Octopus" sp.	Any of the arms	Straughan (1957), Lane (1960)
		O. defilippi	Any of the Arms	Jatta (1896)
		ARGONAUTACEA		
Tremoctopodidae	*Tremoctopus* (inc. *Philonexus*, in part)	*T. violaceus*	Dorsal arms of female	Portmann (1952), Young (1959)
		T. violaceus and others	Hectocotylized arm of male	Steenstrup (1857), Robson (1926, 1932)
Ocythoidae	*Ocythoe* (inc. *Philonexus*, in part)	*O. tuberculata* and others	Hectocotylized arm of male	Hoyle (1908), Robson (1926), Lane (1960)
Argonautidae	*Argonauta*	*A. argo* and others	Hectocotylized arm of male	Steenstrup (1857), Robson (1932), Young (1959), Lane (1960)

DISCUSSION

Autotomy, as the term is used in this paper, does not encompass ontogentic losses. In the pteropod *Herse columnella,* and possibly in the Argonautacea, abscission of the male copulatory apparatus can be regarded as a loss of this type. The former is included in this paper as an instance of autotomy because of the lack of information on the circumstances under which actual separation takes place. The latter is included for the same reason and because it is not positively known whether regeneration does or does not occur. Both phenomena might fall under reproductive autotomy in Giard's classification. However, that evasive qualities are involved seems to be a possibility.

I have seen no references to parasitic autotomy in the Mollusca. Furthermore, what might be interpreted as instances of economic autotomy in the phylum, as in *Peltodoris atromaculata, Limax marginatus,* and *Solen rosaceous,* seem always to be unnatural reactions brought about by preservation or by unfavorable laboratory conditions. Identical, but probably evasive responses are known to occur naturally in related forms. Some instances of economic autotomy, however, have not been observed outside the laboratory (for example, in scaphopods).

Therefore, in my opinion, the great majority of instances of autotomy in the Mollusca have, or, where definitive information is lacking, can reasonably be predicted to have, evasive qualities. In most instances, the natural predator or the situation inciting autotomy is unknown and can only be surmised at this time.

The part to be autotomized is directly exposed to the environment as a projecting extremity. In some instances, for example, the cerata of opisthobranchs and many of the tentacles of *Lima,* the autotomous parts are upwardly directed, more or less perpendicular to the direction taken during locomotion. This position might suggest a large or natant predator that normally approaches from above. In other instances, the autotomous portion is the last, or most posteriorly projecting part of the body. Gastropods that shed the tail-end of the foot, bivalves that release fragments of the siphons, and cephalopods that autotomize parts of the arms, which are trailed behind during escape locomotion, are called to mind. In these examples autotomy takes place in a direction opposite that taken during locomotion, and the autotomous piece is that likely to be first seized by a pursuing organism. Other instances more difficult about which to conjecture include those nudibranchs that shed any portion or whole of the mantle edge, scaphopods that lose the

anterior captacular bundles, and *Solen siliqua,* which has been said to pinch off the tip of the foot.

Pilsbry (1948) reported that the body cavity, and hence the vital organs of *Prophysaon* do not extend into the autotomous end of the foot. Such may also be deduced from Quoy and Gaimard's description (1832) to be true of *Harpa.* Indeed, in every example, organs necessary for continued existence of the individual would never be expected to be included in the part lost, although in most instances anatomical details are not known.

Most of these mollusks have one or more restricted zones of weakness and localized arrangements to facilitate autotomy. Nudibranchs that lose the edge of the mantle and octopods that autotomize variously sized pieces of the arms are examples of mollusks having a more or less diffuse autotomous capability.

There is a significant dichotomy in the ways in which the Mollusca replace lost parts. Most often, removal of a piece of the anatomy results in a distal proliferation of cells at the site of the wound. This is regeneration in the strict sense and normally results in the production of a single part, in appearance quite like that lost.

The captacula of scaphopods, the siphons of *Solecurtus* and *Solen,* and the dorsal arms of *Tremoctopus* are autotomous organs in which the part lost is serially replaced rather than regenerated. The mantle tentacles of *Lima* are possibly also to be included here, if these grow from the base rather than at the tip. In serial replacement there is a proximal zone of proliferation that is presumably always in activity and that forces older portions outwardly, much as in strobilization of a cestode flatworm or of a coelenterate scyphistoma. Whether proximal proliferation is actually continuous, or is stimulated by injury to more distal autotomous elements, poses a fascinating question. Serial replacement seems to have advantages over regeneration in that a new and functional element is immediately available, while in regeneration some variable, and perhaps critical period of time is required before a new element is produced.

Finally, most autotomous structures in the Mollusca play some other, more usual role in the physiology of the organism, perhaps in locomotion, respiration, or feeding. Rarely, as in females of *Tremoctopus,* does the part to be autotomized seem to have no other role than that of decoy. In this sense autotomy may be regarded as a specialized condition superimposed upon the normal functions of an organ. It is, however, a condition having its source in the primitive ability of all organisms to regenerate parts lost to hostile factors or accidents of the environment.

ACKNOWLEDGMENTS

The above reported observations of *Solen sicarius* were made while the author was on a grant from the Office of Naval Research, Department of the Navy, and the University of Washington, NR 104-142. It is a pleasure to acknowledge Dr. R. L. Fernald, Director of the Friday Harbor Laboratories, and Dr. D. L. Ray for their aid and consideration during my tenure there.

Mr. Allyn G. Smith took the photograph of *Lima* and gave permission to include it here. He, Dr. Dwight Taylor, Mr. Lawrence C. Andrews, and Mr. Paul Gregory directed me to references on autotomous mollusks or related matters. Dr. A. Portmann, University of Basel, kindly permitted me to use his figure of *Tremoctopus*. Mr. Steve D. Nagy translated significant parts of the reference by Rawitz. Dr. Ralph I. Smith, Dr. Ross Pohlo, and Mr. Dustin Chivers had cogent criticisms of the original manuscript. Miss Joan Steinberg and Dr. Melbourne R. Carriker helped, respectively, with the taxonomy of nudibranchs and with possible sources of ecological information. To all these persons I hereby express my sincere appreciation.

This work has been supported by National Science Foundation Grant GB 1535.

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No. 62, 23 pages, 32 figures. February 28, 1967.

NEW SOUTHEAST PACIFIC ECHINOIDS

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ABSTRACT: A sample dredged from a guyot on Nasca Ridge during the Scripps Institution of Oceanography expedition DOWNWIND to the southeastern Pacific contains fossil hermatypic corals indicative of post-Oligocene shallow tropical bottom conditions and a unique modern fauna. The four echinoids from this fauna represent genera which had not been recognized previously in the southeastern Pacific area. They include *Stereocidaris nascaensis*, new species; *Salenia scrippsae* Zullo and Allison, 1964 (described from this sample in an earlier paper); *Echinocyamus incertus* H. L. Clark, 1914; and a new genus and species of the family Asterostomatidae, *Scrippsechinus fisheri*, new genus, new species.

1. This is the fourth in a series of papers resulting from the Scripps Institution of Oceanography DOWNWIND Expedition, on the fauna of a guyot on Nasca Ridge (Hubbs, 1959; Zullo *et al.*, 1964; Zullo and Newman, 1964).

Introduction

The accelerating rate of oceanographic exploration which is evident in the massive array of literature published during the past two decades has produced many fundamental contributions to a comprehensive knowledge of the oceanology, geology, and biology of the submerged, or major, part of the earth's surface. Yet, great areas remain sparsely sampled and scarcely known. Oceanic areas of the southeastern Pacific are especially neglected. Bottom samples, other than sediment cores (Menard, 1964, fig. 13), have been taken from widely separated spots and leave much that is unknown.

A gross ignorance of the southeastern Pacific benthos inhabiting seamounts and guyots off the west coast of South America is suggested by the disproportionately large contribution to a knowledge of living Echinoderm-ata made by the contents of a single dredge haul. Four echinoid species recovered by the University of California Scripps Institution of Oceanography expedition DOWNWIND are taxonomic and biogeographic novelties: they represent new or meagerly understood species belonging to higher taxa previously known only in areas remote from the southeastern part of the Pacific Ocean.

One of the species, *Salenia scrippsae* Zullo and Allison, 1964, has been described elsewhere (Zullo, Kaar, Durham, and Allison, 1964), *Stereocidaris nascaensis,* new species, represents a small group of *Stereocidaris* species, otherwise known only in Japanese waters, whose large globiferous pedicellariae bear a solitary end tooth. The third new species, *Scrippsechinus fisheri,* new genus and new species, is a member of the enigmatic family Asterostomatidae and is the only known member of the Order Spatangoida possessing adapically a considerable number of uniserial ambulacral plates. A fourth species, the clypeasteroid *Echinocyamus incertus* H. L. Clark, 1914, is recorded for the first time in the eastern Pacific.

The four species, represented by numerous specimens, were taken in a biological dredge sample, HD-73 (= University of California Museum of Paleontology locality B-6555) obtained by the Research Vessel *Horizon* on 26 January 1958, as that vessel participated in the 1957-1958 DOWNWIND cruise of the International Geophysical Year (Fisher, 1958). Reference to that sample henceforth will appear as "HD-73."

Location

Dredge sample HD-73 was taken from one of the many unnamed guyots between Isla de Pascua (Easter Island) and the South American mainland. The sampled guyot, called "Shoal Guyot" in an earlier publication (Zullo, Kaar, Durham, and Allison, 1964), is located near the juncture of Nasca Ridge with the Easter Island Fracture Zone (Menard, 1964), approximately 1540 kilometers distant from the coast of Chile and 550 kilometers N. 80° W.

from Isla San Felix. Its coordinates include longitude 85° 25' W. and latitude 25° 44' S., the reported location of HD-73. The breadth of the guyot where crossed by the ship is approximately 16 kilometers with a flat upper surface at a minimum depth of 210 meters. Slightly elevated edges of the guyot, with approximate summit depths of 205 meters on the southwestern side (the side approached by the R. V. *Horizon* during its dredging run) and 210 meters on the northeastern side, suggest a rimmed feature. Sample HD-73 was recovered from the central part of the guyot surface, inside of the elevated edges. The length of the dredging run was approximately 3 kilometers, at depths ranging from 227 meters to about 210 meters.

A second sample, HD-72, was dredged earlier during the same day from another Nasca Ridge prominence located a few kilometers to the northeast of the guyot from which HD-73 was recovered. Coordinates of HD-72 are longitude 85° 14' W. and latitude 25° 31' S. Depths recorded during the dredging run range from about 950 meters to 870 meters, possibly representing the southern flank of a northward shoaling feature. Notes concerning the fossils from that sample are presented in the preliminary expedition report (Fisher, 1958).

January water temperatures at 200 meters in the vicinity of both sample localities are indicated as near 14° C. by interpolation of data from nearest hydrographic casts (Fisher, 1958). Surface temperatures are near 22° C.

Contents of HD-73

Sample HD-73 was reported at the time of its recovery to consist of "50-100 lbs." of shell debris including "...hundreds of live pelecypods, limas, a few pectens, large gastropods, brachiopods, and gorgonians." Noted also were "...a few pieces of coral and much calcareous rock." (Fisher, 1958). No sediment sample was taken but gut contents of specimens of one of the echinoid species, described below, provide clues to the nature of modern sediments on and around the guyot. Neither sample HD-73 nor HD-72 contained volcanic rocks. The organic contents of HD-73 are listed on table 1.

Echinoids from HD-73 are preserved in the type collection of the University of California Museum of Paleontology, Berkeley (type numbers are given with descriptions of individual species). Some of the coralline algae and the coral debris are stored in the general collections (as locality B-6555) of the same institution. Additional calcareous debris is held by the University of California Scripps Institution of Oceanography at La Jolla. Types of the barnacles (Zullo and Newman, 1964) are in type collections of the University of California Museum of Paleontology and the United States National Museum. Other crustaceans and echinoderms are stored in collections of the University of Southern California, Allan Hancock Foundation, Los Angeles. A fish incidentally captured in the HD-73 rock dredge sample (Hubbs,

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1959) is in the ichthyological collections of Scripps Institution of Oceanography. The present location of sorted mollusks from this sample is unknown.

Fossils

Indurated corals, coralline algae, and part of the mollusk shell debris of HD-73 probably represent a fossil reef assemblage. The recorded dredging depth (between 227 and 210 meters) and the local minimum "rim" depth of the guyot (205 meters) exceed the known living range of comparable modern reef faunas, but the contents of the sample, as well as the physiography of the feature, offer unmistakable evidence of a drowned island or bank, possibly an atoll.

The most abundantly represented coral genera, identified by Durham as *Leptoseris, Pocillopora,* and *Porites,* are not known to live together at depths greater than 40 meters (Clipperton Island), although *Leptoseris* and *Porites* have depth ranges which extend downward to at least 110 meters and 55 meters, respectively (Wells, 1954). A few specimens of a fourth genus, *Stylophora,* exhibit a relatively fresh appearance which suggests that they are younger than the rest of the coral assemblage. Possibly *Stylophora* still lives in the area on an unrecorded though unlikely shallow prominence on the guyot surface. Possibly this occurrence represents a greater depth than has been recorded for the genus (45 meters) or for other hermatypic corals (?155 meters). Cool water temperatures at depths comparable to that of the guyot's surface suggest that the last alternative is least likely, if *Stylophora* still lives there.

An additional hermatypic coral genus occurs on an adjacent Nasca Ridge prominence in Sample HD-72. That genus is *Plesiastrea* [*Plesiastrea* sp., *cf. P. versipora* (Lamarck, 1816)] which was reported by J. W. Wells (Fisher, 1958) to occur with *Porites* and *Stylophora* [*S. pistillata* (Esper, 1797)]. *Plesiastrea* does not occur in the material examined by us.

Diverse states of preservation exhibited by corals from sample HD-73 suggest that they are not all of the same age. Indeed, some, such as *Stylophora,* may still live on the guyot. A more careful analysis of the precise identity of these corals will be required before a decision can be reached concerning their significance as evidence for the earliest occurrence of shallow water in that area and thus as evidence of the history of Nasca Ridge.

The reported identity of corals from HD-72 is more revealing. *Stylophora pistillata* (Esper, 1797) ranges from Middle Miocene to Recent in the Indo-Pacific (Wells, 1964). The genus *Plesiastrea* is not known to occur in rocks older than Miocene anywhere. Manganese nodules bearing late Tertiary calcareous ooze are reported in a dredge sample from Nasca Ridge (Fisher, 1958), but neither the criteria for this age determination nor the exact location of the sample is presented in the preliminary expedition report.

TABLE 1. *The contents of HD-73* (Taxa represented by living specimens or interpreted as modern unless indicated otherwise)

ALGAE:	Unidentified coralline algae (? fossil)	
FORAMINIFERS:	*Homotrema.*	
	Sedimentary gut contents of *Scrippsechinus fisheri,* new genus and new species, consists mostly of planktonic species.	
CORALS:	*Stylophora* (? fossil) [HD-72 specimens identified as *Stylophora pistillata* (Esper, 1797)]	
	Pocillopora (fossil)	
	Leptoseris (fossil)	
	Porites (fossil)	
BRYOZOANS:	Not identified	
ANNELID WORMS:	Encrusting calcareous tubes not identified (living?)	
MOLLUSKS:	*Turbonilla (Strioturbonilla)*	*Glycymeris* (? living)
	Xenophora (? living)	*Ctena* (?living)
	Colus	*Acesta*
	Pteropods in gut contents of *Scrippsechinus fisheri,* new genus and new species	
	Arcopsis (? living)	
CIRRIPEDIA:	*Megalasma (Megalasma) elegans* Newman, 1964	
	Heteralepas mystacophora Newman, 1964	
	Verruca (Verruca) scrippsae Zullo, 1964	
	Balanus (Solidobalanus) nascanus Zullo, 1964	
DECAPODA:	Unidentified	
ECHINOIDEA:	*Salenia scrippsae* Zullo and Allison, 1964	
	Stereocidaris nascaensis, new species	
	Echinocyamus incertus Clark, 1914 (from gut contents of *Scrippsechinus fisheri,* new genus and new species	
	Scrippsechinus fisheri, new genus and new species	
PISCES:	*Pterygotrigla picta* (Gunther, 1880)	

MODERN FAUNA

The modern fauna sampled by HD-73 consists of both living and non-living specimens. A great abundance of fresh shells of certain species is interpreted as evidence that those species still live in the area, although no living specimens happened to have been taken.

Foraminiferida: Adherent tests of the genus *Homotrema* appear to represent the only foraminifers which might have been living when taken in the dredge haul. Tests of foraminifers, almost entirely planktonic, which are the major part of the gut contents of the new asterostomatid echinoid described below, also must represent largely species now living on the bottom and in the overlying water column.

Bryozoa: Delicate bryozoans encrusting some of the shell debris of HD-73 certainly represent the living fauna of that area. They have not been identified.

Annelida: Calcareous tubes of unidentified serpulid worms are attached to many shell surfaces.

Mollusca: Living specimens of the gastropods *Turbonilla (Strioturbonilla)* and *Colus* and of the bivalve *Acesta* are recorded in the notes of Allison taken during the preliminary sorting of HD-73. Disassociated valves of *Acesta* are noted as abundant. Non-living mollusks recorded at that time include a few specimens each of *Xenophora, Arcopsis,* and *Glycymeris*. Numerous pteropods are associated with the planktonic foraminifers of the echinoid gut contents.

Crustacea: The recently described barnacle fauna of HD-73 (Zullo and Newman, 1964) consists of four species belonging to three suborders. The suborder Lepadomorpha includes *Megalasma (Megalasma) elegans* Newman, 1964, and *Heteralepas mystacophora* Newman, 1964, of this sample. The suborders Verrucomorpha and Balanomorpha are represented respectively by *Verruca (Verruca) scrippsae* Zullo, 1964, and *Balanus (Solidobalanus) nascanus* Zullo, 1964. Closest relatives of these species are distributed generally in the Indo-Pacific province. The study of decapod crustaceans of HD-73 has not yet been completed.

Echinoidea: The class Echinoidea is represented in HD-73 by specimens of the recently described *Salenia scrippsae* Zullo and Allison, 1964, and numerous specimens of *Echinocyamus incertus* Clark, 1914, a new species of *Stereocidaris,* and a new species placed in a new genus, *Scrippsechinus,* assigned to the family Asterostomatidae. None of these genera previously has been recorded validly from modern faunas of the eastern Pacific *(Echinocyamus terminalis* Grant and Hertlein, 1938, from Guadalupe Island off northwestern Mexico, is a small representative of the clypeasteroid genus *Dendraster).* All (12) of the Nasca Ridge *Echinocyamus* specimens came from the gut contents of specimens of *Scrippsechinus fisheri,* new genus and new species. None was found in the calcareous debris of comparable size taken in the same dredge haul.

Pisces: HD-73 yielded a single triglid fish (Hubbs, 1959) identified as *Pterygotrigla picta* (Günther, 1880). According to Hubbs, that species is known from Isla Juán Fernández, located south of Nasca Ridge, and from the New Zealand and Australian area.

History of Guyot and Relationships of Faunas

A truncated upper surface, apparently composed entirely of calcareous rock, and fossil hermatypic corals dredged from the central part of that sur-

face indicate past shallow marine conditions over the Nasca Ridge guyot sampled by HD-73. Well's identifications of *Stylophora pistillata* (Esper, 1797) and *Plesiastrea* among hermatypic corals of HD-72 further indicate that such shallow-water conditions have existed in the area at least once since the Oligocene Epoch. Fossil and modern faunal elements of HD-73, furthermore, suggest that a series of shallow-water "stepping stones" once linked Nasca Ridge with the far western Pacific, probably by way of Easter Island and drowned features of the Easter Island Fracture Zone.

The 205-230 meter depths recorded on the upper surface of the sampled guyot exceed the depth at which marine erosion could have been effective during lowered Pleistocene sea levels (100-150 meters below the present sea level) and are below the maximum depth at which reef building processes might effectively produce such a feature (15-25 meters for modern reefs and atolls). A combined affect of both factors (maximum depth 175 meters) is both insufficient and unlikely.

Two possible explanations for the present depth of the guyot's upper surface remain. A volume of water displaced by rising of existing oceanic ridges and rises, just one of the factors which might have altered the capacity of ocean basis through the Cenozoic Period, has been calculated as sufficient to produce a 200 meter elevation of sea level (Menard, 1964). The validity of this possible explanation can be tested by a precise comparison of the age of shallow-water fossils on the guyot with times of general inundation of oceanic islands and structurally stable border areas, but the details of these chronologic relationships are not known now. Such an explanation, if valid, can account for this, the shallowest of several identified and questionably identified Nasca Ridge guyots. Flat tops of other guyots, at approximately 320 and 400 meters (Fisher, 1958) are at depths exceeding the theoretical limits of such a mechanism for late Cenozoic sea level rise. Subsidence of once emergent or shallowly submergent islands or banks is, therefore the most likely explanation for the guyots of Nasca Ridge, including the one from which the sample discussed here (HD-73) was taken. Determination of the extent and time of that subsidence will require the sampling of others of the probably related guyots of Nasca Ridge.

Biogeographic relationships of taxa thus far recognized in the fossil and modern contents of HD-73, and reported in the contents of a related sample HD-72, are clearly with western Pacific areas. Many of the organisms have known living depth ranges restricted to shallow water, in some cases seemingly shallower than that from which they were dredged alive in HD-73. The trans-Pacific dispersal of these elements must have taken place at a time (post-Oligocene) when other islands and banks existed in intermediate areas. A poorly known line of seamounts extending westward from Nasca Ridge to near the southeastern edge of the Tuamotu Archipelago

(Fisher, 1958), and including Easter and Sala y Gomez islands, presents a possible drowned dispersal route along which "stepping stones" might once have been available for successive colonization and radiation of depth restricted organisms. The high incidence of endemism in what is known of the modern Easter Island marine fauna and the uniqueness of certain living elements of HD-73, such as the echinoids described here, suggest that such a dispersal route is no longer available for many organisms.

Problems concerning the geologic history of the sampled Nasca Ridge guyot and the biogeographic history of its faunas will be resolved with precision only when the entire southeastern Pacific area is better understood. The availability of a critical and widely applicable chronologic system, such as that which may be available in the Upper Cenozoic succession of planktonic foraminifers, will provide a necessary perspective in the attainment of these goals. The completion of studies of already available dredged samples and of additional samples taken at locations determined to be critical promise provocative and rewarding reviews of these problems in the future.

Figure 1. *Stereocidaris nascaensis*, new species; aboral view of holotype UCMP 36587, locality B-6555 (×.94).

Figure 2. *Stereocidaris nascaensis*, new species; oral view of holotype UCMP 36587, locality B-6555 (×.94).

Figure 3. *Stereocidaris nascaensis*, new species; aboral view of paratype UCMP 36588, locality B-6555 (×.94).

Figure 4. *Stereocidaris nascaensis*, new species; oral view of paratype UCMP 36588, locality B-6555 (×.94).

Figure 5. *Echinocyamus incertus* H. L. Clark, 1914; oral view of hypotype UCMP 36579, locality B-6555 (×7.0).

Figure 6. *Echinocyamus incertus* H. L. Clark, 1914; aboral view of hypotype UCMP 36579, locality B-6555 (×7.0).

Figure 7. *Echinocyamus incertus* H. L. Clark, 1914; oral view of hypotype UCMP 36580, locality B-6555 (×7.0).

Figure 8. *Echinocyamus incertus* H. L. Clark, 1914; aboral view of hypotype UCMP 36580, locality B-6555 (×7.0).

Figure 9. *Echinocyamus incertus* H. L. Clark, 1914; oral view of hypotype UCMP 36581, locality B-6555 (×7.0).

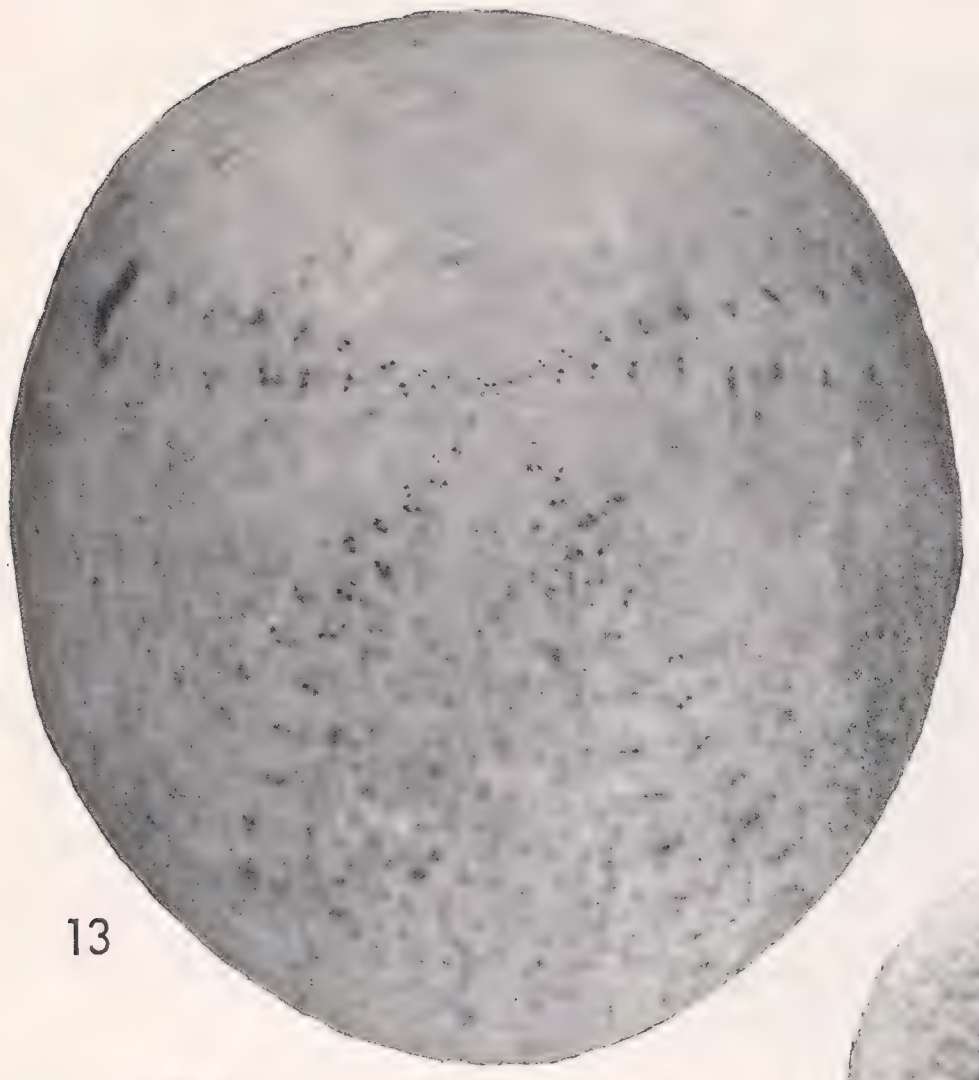
Figure 10. *Echinocyamus incertus* H. L. Clark, 1914; aboral view of hypotype UCMP 36581, locality B-6555 (×7.0).

Figure 11. *Echinocyamus incertus* H. L. Clark, 1914; oral view of hypotype UCMP 36582, locality B-6555 (×7.0).

Figure 12. *Echinocyamus incertus* H. L. Clark, 1914; aboral view of hypotype UCMP 36582, locality B-6555 (×7.0).

Figure 13. *Scrippsechinus fisheri*, new genus and new species; aboral view of paratype UCMP 36578, locality B-6555 (×1.3).

Figure 14. *Scrippsechinus fisheri*, new genus and new species; oral view of paratype UCMP 36578, locality B-6555 (×1.3).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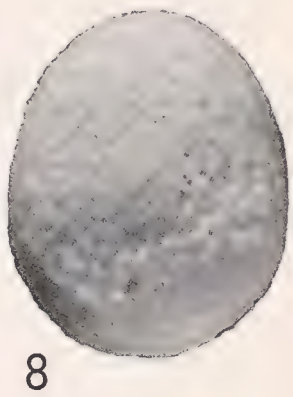
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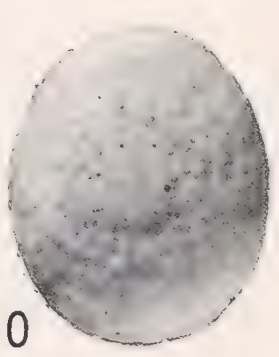
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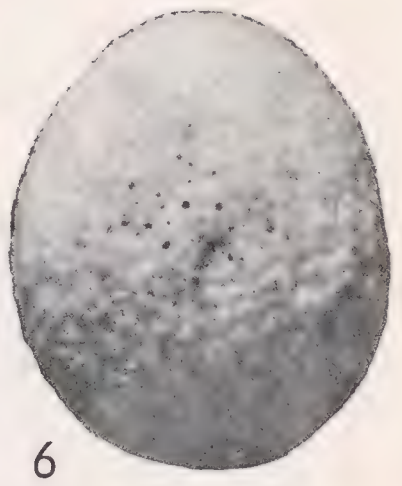
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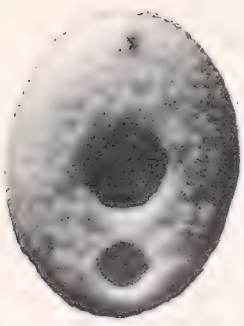
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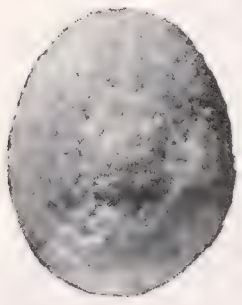
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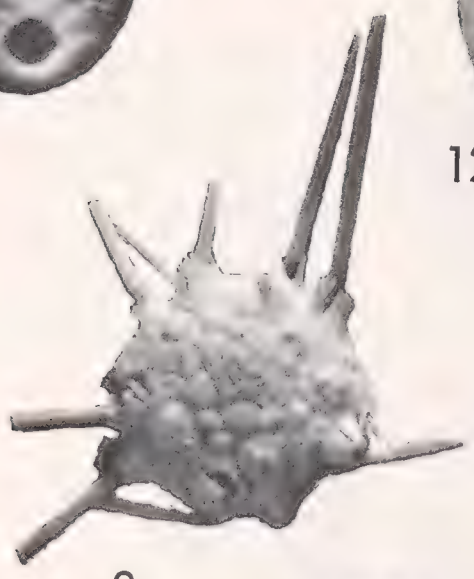
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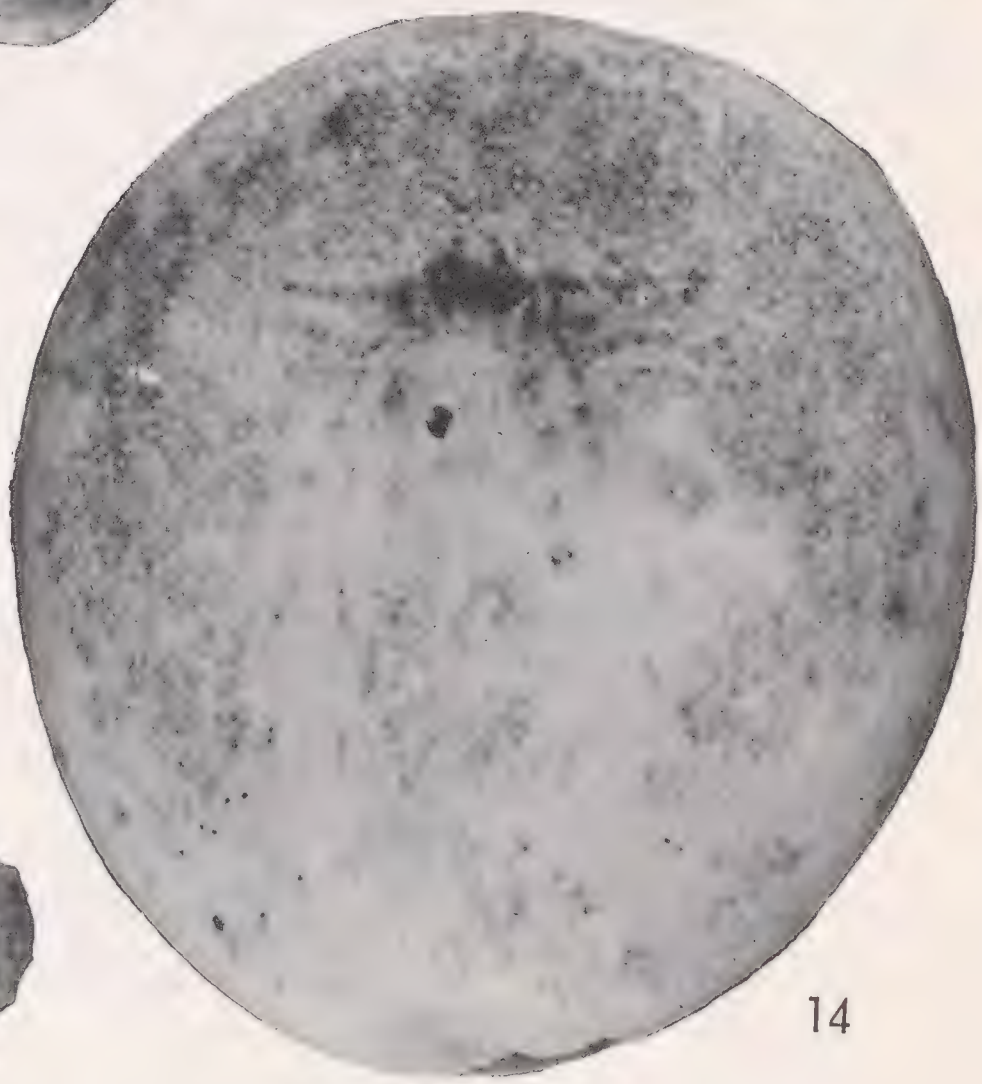
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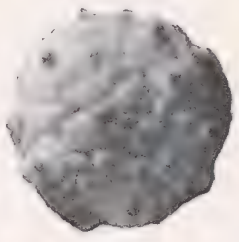
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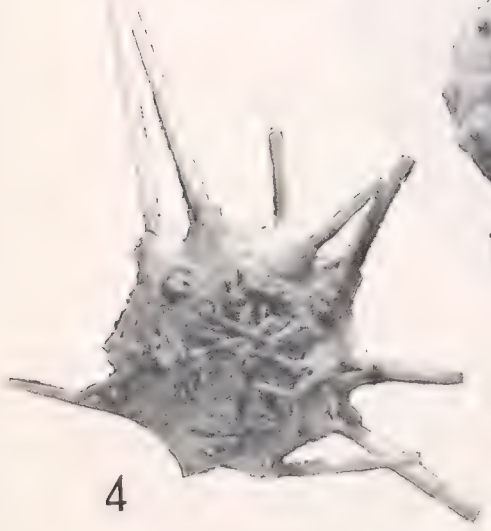
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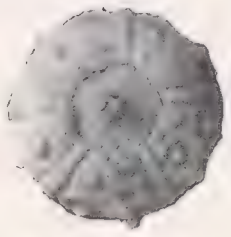
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Systematic descriptions

Class ECHINOIDEA Leske, 1778

Subclass PERISCHOECHINOIDEA McCoy, 1849

Order CIDAROIDA Claus, 1880

Family Cidaridae Gray, 1825

Subfamily Stereocidarinae Lambert, 1900

Genus **Stereocidaris** Pomel, 1883

Stereocidaris nascaensis Allison, Durham, and Mintz, new species.
(Figures 1-4; 15-20.)

Diagnosis. *Stereocidaris* with very large peristome; each ambulacral plate with obliquely oriented pore pairs bordered by interporiferous tubercle triad of large inner tubercle, slightly smaller marginal tubercle, and much smaller interposed miliary tubercle; globiferous pedicellariae including common small form with end tooth and rare large form with widely gaping distal tip.

Description. Test small, depressed (diameter 1.6 × height), with flat oral surface and slightly convex aboral surface.

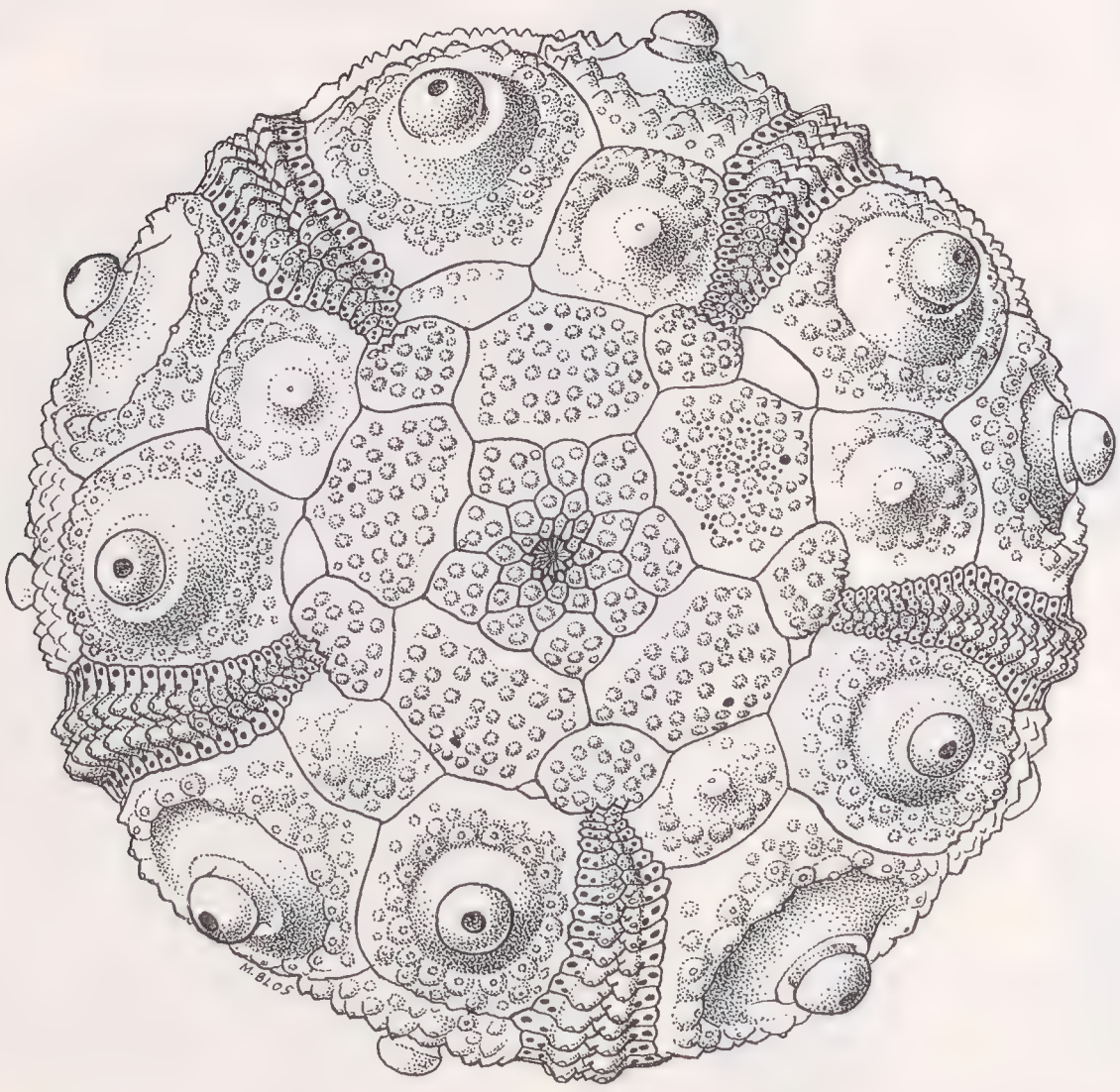
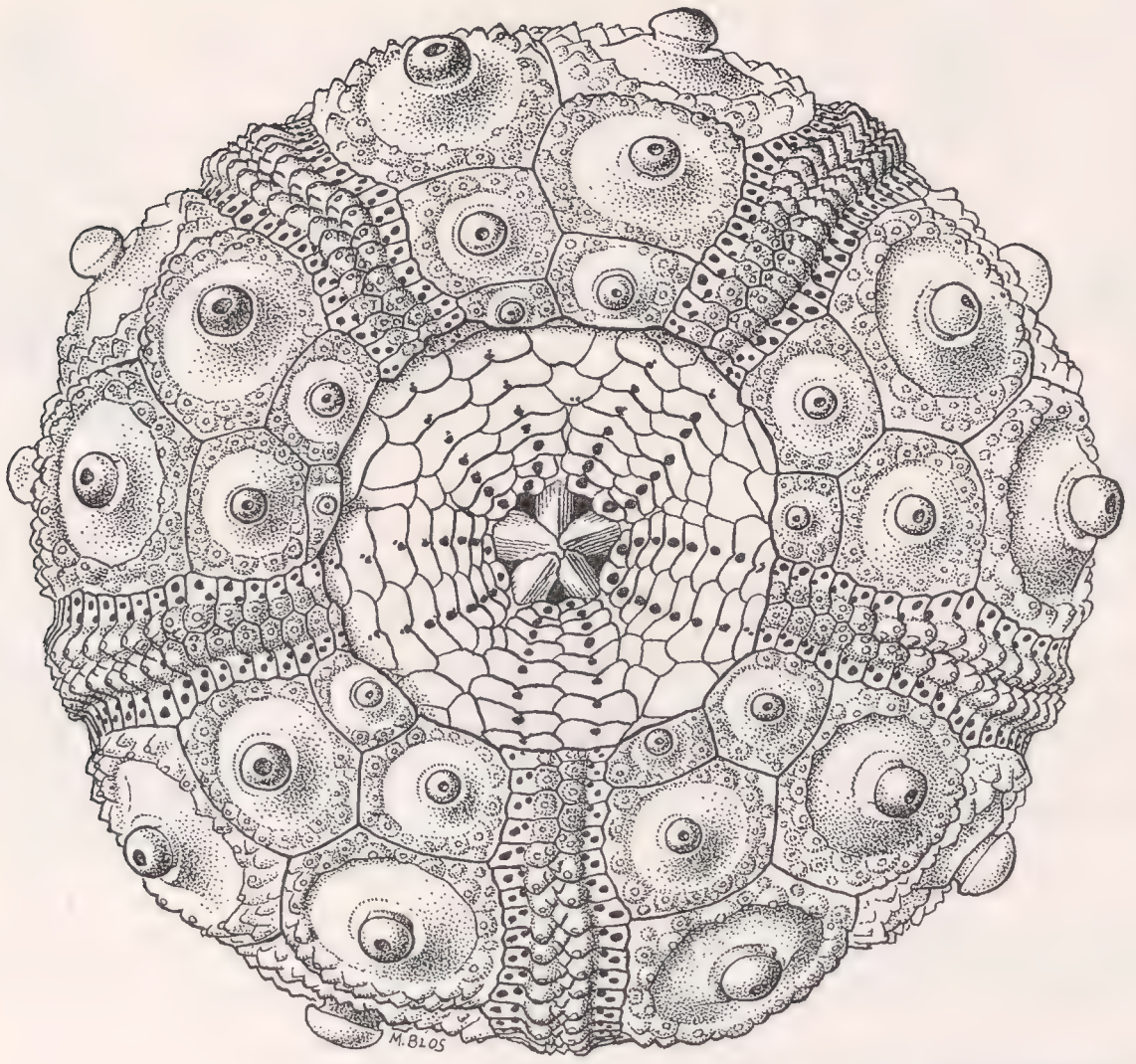


Figure 15. *Stereocidaris nascaensis*, new species; aboral (apical) view of holotype UCMP 36587, locality B-6555 (×4.0).



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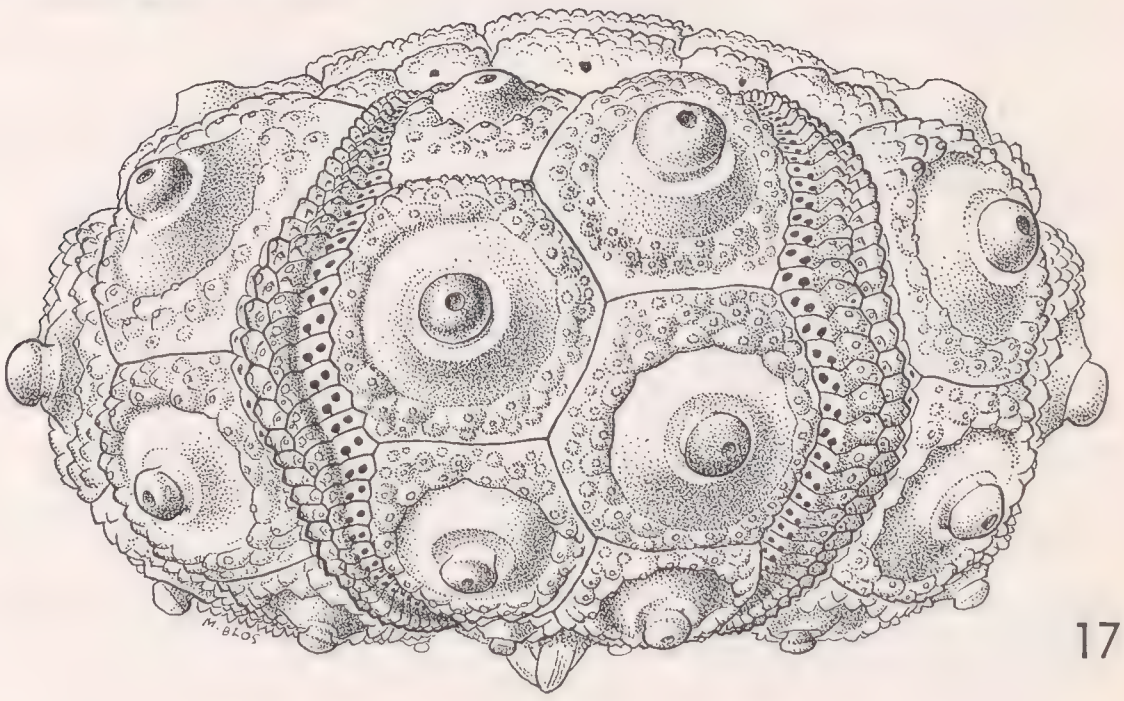

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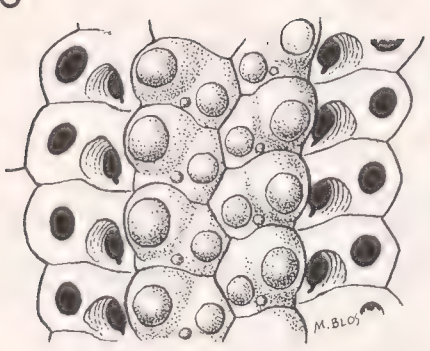

FIGURE 16. *Stereocidaris nascaensis*, new species; oral view of holotype UCMP 36587, locality B-6555 (×4.0).

FIGURE 17. *Stereocidaris nascaensis*, new species; lateral view of holotype UCMP 36587, locality B-6555 (×4.0).

FIGURE 18. *Stereocidaris nascaensis*, new species; ambulacral plates at ambitus of holotype UCMP 36587, locality B-6555 (×10.0).

Ambulacra sinuate, 1/3 width of interambulacra at ambitus; interporiferous areas 1/2 width of ambulacra, with 3 rows of tubercles consisting of large inner tubercles, slightly smaller marginal tubercle, and much smaller miliary tubercle between (fig. 18); pores of equal size, widely separated in pairs oriented obliquely to suture (fig. 18); neuropores present.

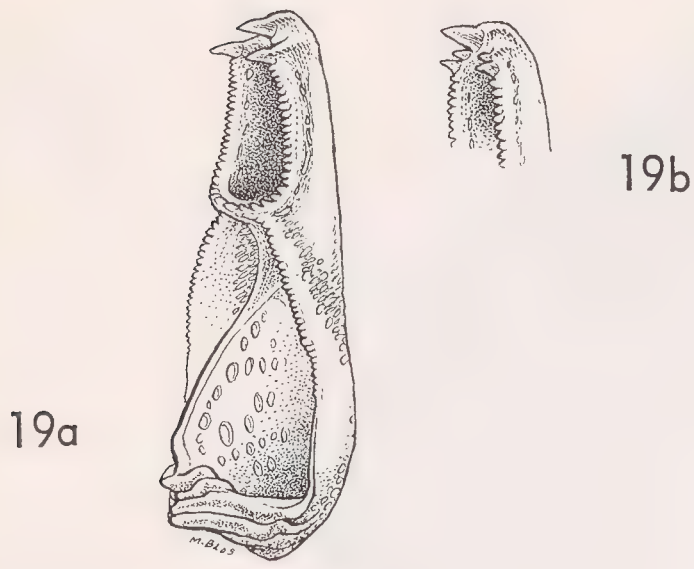

FIGURE 19. *Stereocidaris nascaensis,* new species; small globiferous pedicellariae, holotype UCMP 36587a (figure 19a), and holotype UCMP 36587b (figure 19b), locality B-6555 (×235.0)

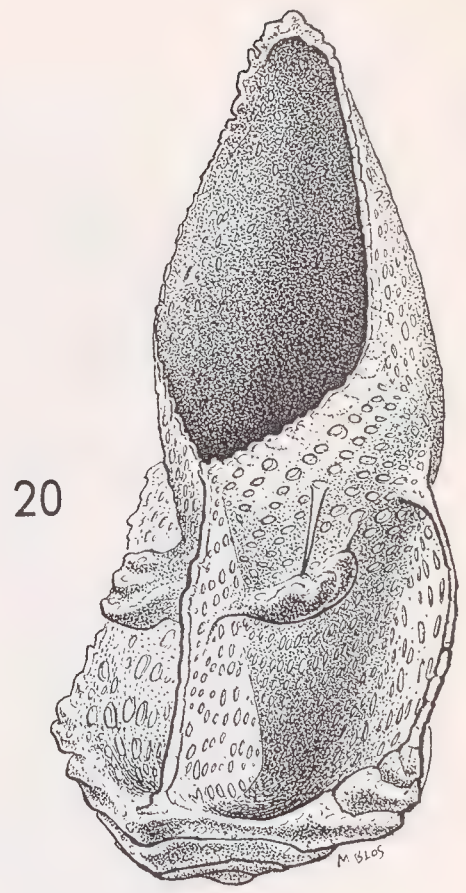

FIGURE 20. *Stereocidaris nascaensis,* new species; rare form of large globiferous pedicellaria, holotype UCMP 36587c, locality B-6555 (×150.0).

Interambulacra of 4-5 plates per column, higher than wide adapically, with raised horizontal sutures adapically (figs. 1, 15); tubercles non-crenulate, surrounded by deep and widely separated areoles; scrobicular tubercles slightly larger than secondary tubercles, secondary tubercles smallest near plate margins (figs. 15, 16, 17).

Apical system inflated, with diameter 1/2 ambital diameter; ocular plates all exsert; genital plates broader than high, with very small genital pores; all apical system plates covered by numerous, small, rudimentary tubercles (fig. 15).

Peristome prominent, with diameter slightly more than 1/3 ambital diameter (35-40 per cent), covered by numerous small plates (fig. 16).

Primary spines large, length possibly two times greater than test diameter, cylindrical, slightly tapered distally; surface delicately sculptured by 10 or 11 longitudinal knobby ridges formed by rows of closely spaced nodes (figs. 3, 4).

Scrobicular spines spatulate, closely arranged around bases of primary spines; secondary marginal and ambulacral spines about 1/3 to 1/2 major scrobicular spines in size, not so distinctly flattened; central oral spines slender, densely arranged over peristomal area; apical spines small, short, spatulate.

Pedicellariae of globiferous forms only; small pedicellariae with distinct end tooth (fig. 19a-b); larger forms with very weak end tooth; rare form of large globiferous pedicellariae with widely expanded opening continuous to distal extremity of valve (fig. 20).

Color of alcohol-preserved specimens faded; probably buff with purplish bases of primary spines.

DISTRIBUTION. Nasca Ridge, 210-227 meters (HD-73).

DIMENSIONS OF TYPES (UNIVERSITY OF CALIFORNIA MUSEUM OF PALEONTOLOGY).

Holotype UCMP 36587 (figs. 1, 2, 15-20). Test with spines removed: height 10.9 mm., diameter 17.3 mm., peristome diameter 6.9 mm.

Paratype UCMP 36588 (figs. 3, 4). Test with spines in place: height 13.0 mm., diameter 19.5 mm.

Holotype UCMP 36587a (fig. 19a). Valve of small globiferous pedicellaria from holotype (UCMP 36587): length .16 mm.

Holotype UCMP 36587b (fig. 19b). Valve of small globiferous pedicellaria from holotype (UCMP 36587): length .19mm.

Holotype UCMP 36587c (fig. 20). Valve of rare form of large globiferous pedicellaria from holotype UCMP 36587): length .41 mm.

REMARKS. The new Nasca Ridge species is assigned to the genus *Stereocidaris* on the basis of the following features: rudimentary apical primary tubercles; incised aboral interambulacral sutures; widely separated scrobiculae on adjacent interambulacral plates; sinuate ambulacra.

The genus *Stereocidaris* has a stratigraphic record extending into the Cretaceous System and is represented by many species in modern seas. Almost all of the living species are restricted to the Indo-Pacific area; no living examples of *Stereocidaris* have been reported previously from eastern Pacific areas.

Most species of *Stereocidaris* have globiferous pedicellariae lacking the end tooth which occurs on small pedicellariae of *S. nascaensis*, new species. Two exceptional species, sharing these pedicellariae characteristics with *S. nascaensis*, new species, are *S. sceptriferoides* (Doderlein, 1887) and *S. japonica* (Doderlein, 1885) which live off Japan at depths from 70 to 700 meters (Mortensen, 1928, pp. 225-284). *Stereocidaris nascaensis* can be distinguished from these species by its characteristic ambulacral tubercle pattern, very large peristome, and peculiar large globiferous pedicellariae.

Subclass EUECHINOIDEA Bronn, 1860

Superorder ECHINACEA Claus, 1876

Order SALENIOIDA Delage and Hérouard, 1903

Family Saleniidae Agassiz, 1838

Subfamily Saleninae Agassiz, 1838

Genus **Salenia** Gray, 1835

Salenia scrippsae Zullo and Allison, 1964.

Salenia scrippsae Zullo and Allison, 1964, pp. 339-343, pl. 56, figs. 1-4, text figs. 3-4.

Diagnosis. Living *Salenia* with partially bigeminate ambulacral plates, complexly sculptured apical system, and tricolour banded primary interambulacral spines which are longitudinally ribbed but not verticillate.

Distribution. Nasca Ridge (HD-73).

The specimens of this species, known only from HD-73, have been described separately (Zullo, *et al.*, 1964). These specimens are catalogued in the type collection of the University of California Museum of Paleontology as UCMP 30756 through 30763.

Superorder GNATHOSTOMATA Zittel, 1879

Order CLYPEASTEROIDA A. Agassiz, 1873

Suborder Laganina Mortensen, 1948

Family Fibulariidae Gray, 1855

Genus **Echinocyamus** Van Phelsum, 1774

Echinocyamus incertus H. L. Clark, 1914.

(Figures 5-12.)

Fibularia australis A. Agassiz and H. L. Clark, 1907, p. 247, (not *Fibularia australis* Desmoulins, 1835; not *Fibularia australis* Benham, 1911).
Echinocyamus incertus H. L. Clark, 1914, p. 64, pl. 128, figs. 1-3.
Fibularia incerta Lambert and Thiéry, 1925, p. 577.
Echinocyamus incertus H. L. Clark; Mortensen, 1948, pp. 193-194.

Diagnosis. Small, elongate-oval, moderately arched *Echinocyamus* with meagerly developed, non-convergent, ambulacral pore series limited to central aboral surface, and with ocular pores much smaller than genital pores.

DISTRIBUTION. Hawaiian Islands, 20-360 meters, and Nasca Ridge, 210-227 meters (HD-73).

DIMENSIONS AND AMBULACRAL PORE DEVELOPMENT OF TYPES (UNIVERSITY OF CALIFORNIA MUSEUM OF PALEONTOLOGY)

Hypotype UCMP 36579 (figs. 5, 6). Test without spines: length 4.2 mm., width 3.6 mm., height 1.7 mm., width of periproct 0.8 mm.; 9 pores in ambulacrum III (2 pairs on each side partially developed).

Hypotype UCMP 36580 (figs. 7, 8). Test without spines: length 3.2 mm., width 2.6 mm., height 1.3 mm., width of periproct 0.6 mm.; 4 pores in ambulacrum III (1 pair on each side).

Hypotype UCMP 36581 (figs. 9, 10). Test without spines: length 3.0 mm., width 2.5 mm., height 1.2 mm., width of periproct 0.5 mm., 4 pores in ambulacrum III (1 pair fully developed on each side), additional pores not completely developed.

Hypotype UCMP 36582 (figs. 11, 12). Test without spines: length 2.7 mm., width 2.5 mm., height 1.1 mm., width of periproct 0.4 mm.; 3 pores in ambulacrum III (1 partially developed pore on each side), several partially developed pores.

REMARKS. *Echinocyamus incertus* is represented in the Nasca Ridge sample (HD-73) by 6 nearly complete specimens, four of which are designated as hypotypes (UCMP 36579, 36580, 36581, and 36582), and by fragments of 5 others. All were obtained in the gut contents of specimens of *Scrippsechinus fisheri,* new genus and new species.

Clark had only a single specimen with dimensions as follows: length 6 mm., width nearly 5 mm., height nearly 2 mm., width of peristome 1.2 mm., width of periproct 0.6 mm., anterior petal with four pore pairs on each side. Mortensen (1948, pp. 193-194) reported 3 specimens, the largest of which is 3 mm. long.

The Nasca Ridge specimens are slightly more arched on the upper surface than the holotype and have a slight lateral angularity to the periproct not apparent in the Hawaiian material. Tuberculation and number of pore pairs appear to vary with size as would be expected from the information available on the Hawaiian representatives of the species (H. L. Clark, 1914, p. 64, pl. 128, figs. 1-3; Mortensen, 1948, pp. 193-194).

This species has been previously reported only from the Hawaiian Islands and at depths of 20 to 360 meters.

Superorder ATELOSTOMATA Zittel, 1879

Order SPATANGOIDA Claus, 1876

Family Asterostomatidae Pictet, 1897

(=Paleopneustidae Agassiz, 1904; Antillasterinae Lambert and Thiéry, 1924; Palaeopneustidae Mortensen, 1950)

Genus **Scrippsechinus** Allison, Durham, and Mintz, new genus

Diagnosis. Inflated, apetalous, ovoid to slightly elongate, asterostomatid lacking fascioles, and with fused genital plates, 4 genital pores, numerous uniserial ambulacral plates near apical system; ambulacral pores paired, except near peristome, in paired ambulacra, minute single pores in frontal ambulacrum.

Type species. *Scrippsechinus fisheri,* new species.

Discussion. The unique features exhibited by *Scrippsechinus fisheri,* known only from Nasca Ridge (HD-73), require that it be distinguished as a new monotypic genus. These features are described and their relationships discussed following treatment of that species.

The generic name, *Scrippsechinus,* acknowledges the contributions of the Scripps Institution of Oceanography to the knowledge of the southeastern Pacific area from which this echinoid was collected.

Scrippsechinus fisheri Allison, Durham, and Mintz, new species.

(Figures 13-14; 21-32.)

Diagnosis. As for the genus.

Description. Test large, thin-shelled, semi-globose, ovoid to slightly elongate in outline (table 2; figs. 13, 14, 21, 22); anterior end without frontal depression; posterior end not truncated except in immediate area of periproct (fig. 23).

Ambulacral plates large, with height about ½ height of adjacent interambulacral plates; arranged adapically in irregular uniserial columns in-

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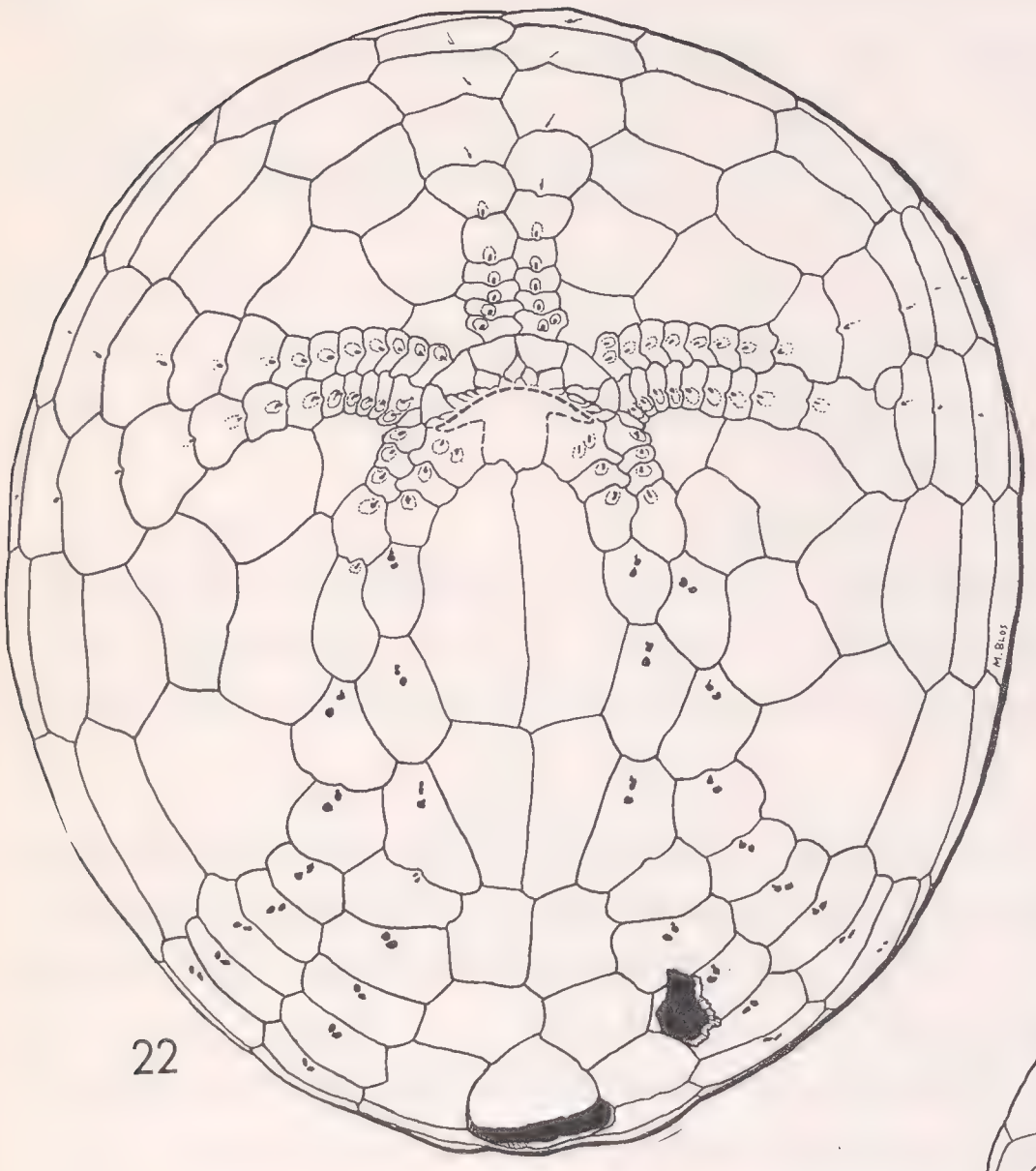
Figure 21. *Scrippsechinus fisheri,* new genus and new species; aboral view of holotype UCMP 36575, locality B-6555 (× 1.25).

Figure 22. *Scrippsechinus fisheri,* new genus and new species; oral view of paratype UCMP 36572, locality B-6555 (×1.25).

Figure 23. *Scrippsechinus fisheri,* new genus and new species; lateral view of holotype UCMP 36575, locality B-6555 (×1.25).

Figure 24. *Scrippsechinus fisheri,* new genus and new species; peristome of paratype UCMP 36573, locality B-6555 (× 3.0).

Figure 25. *Scrippsechinus fisheri,* new genus and new species; periproct of paratype UCMP 36573, locality B-6555 (× 4.2).



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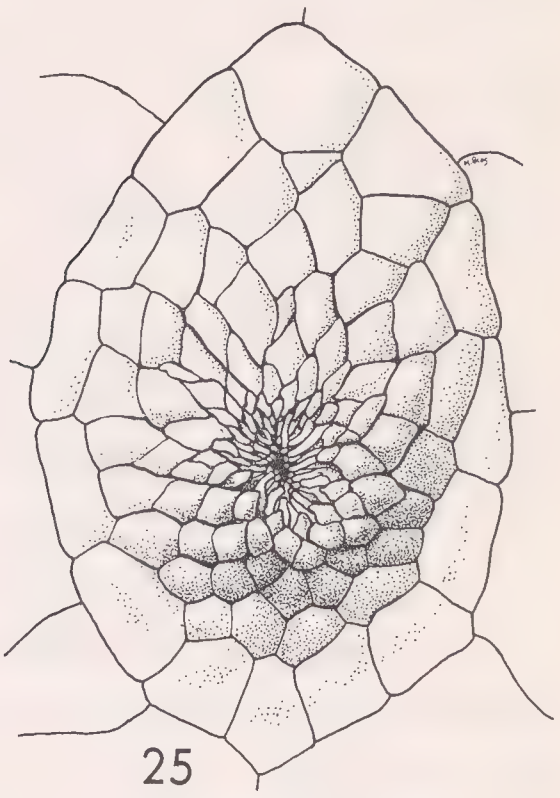

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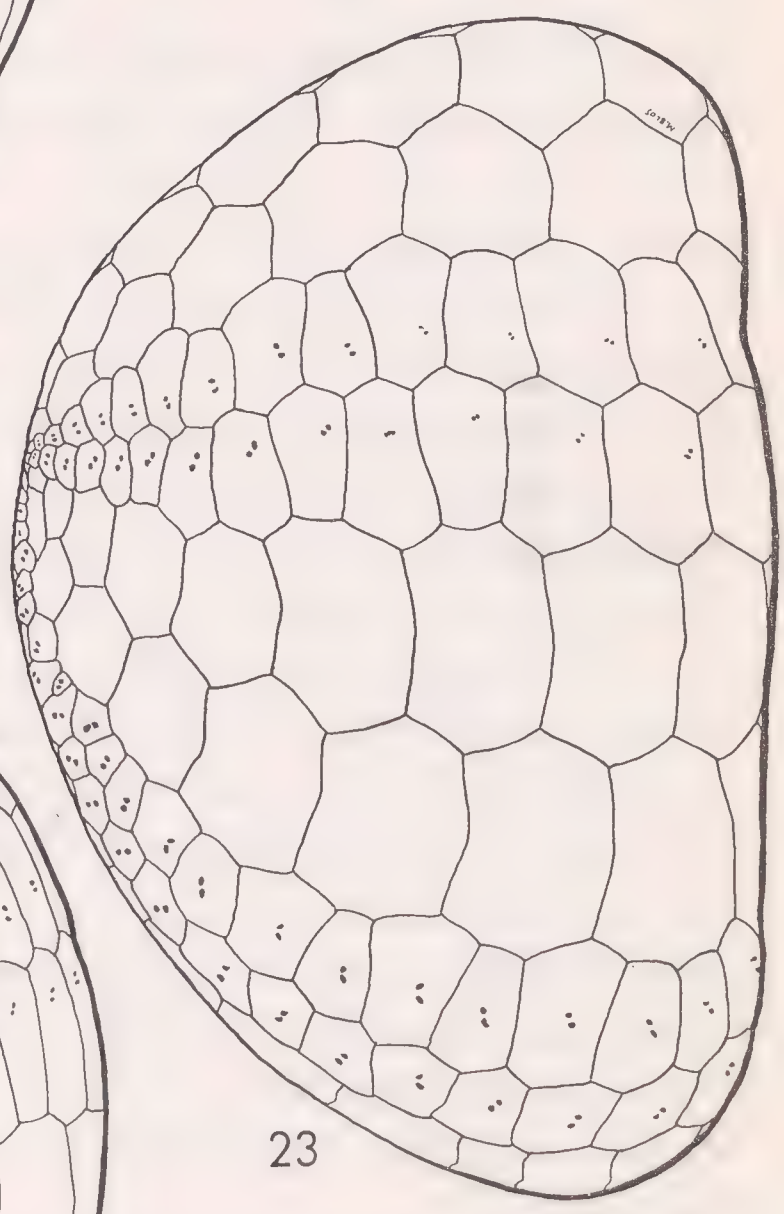

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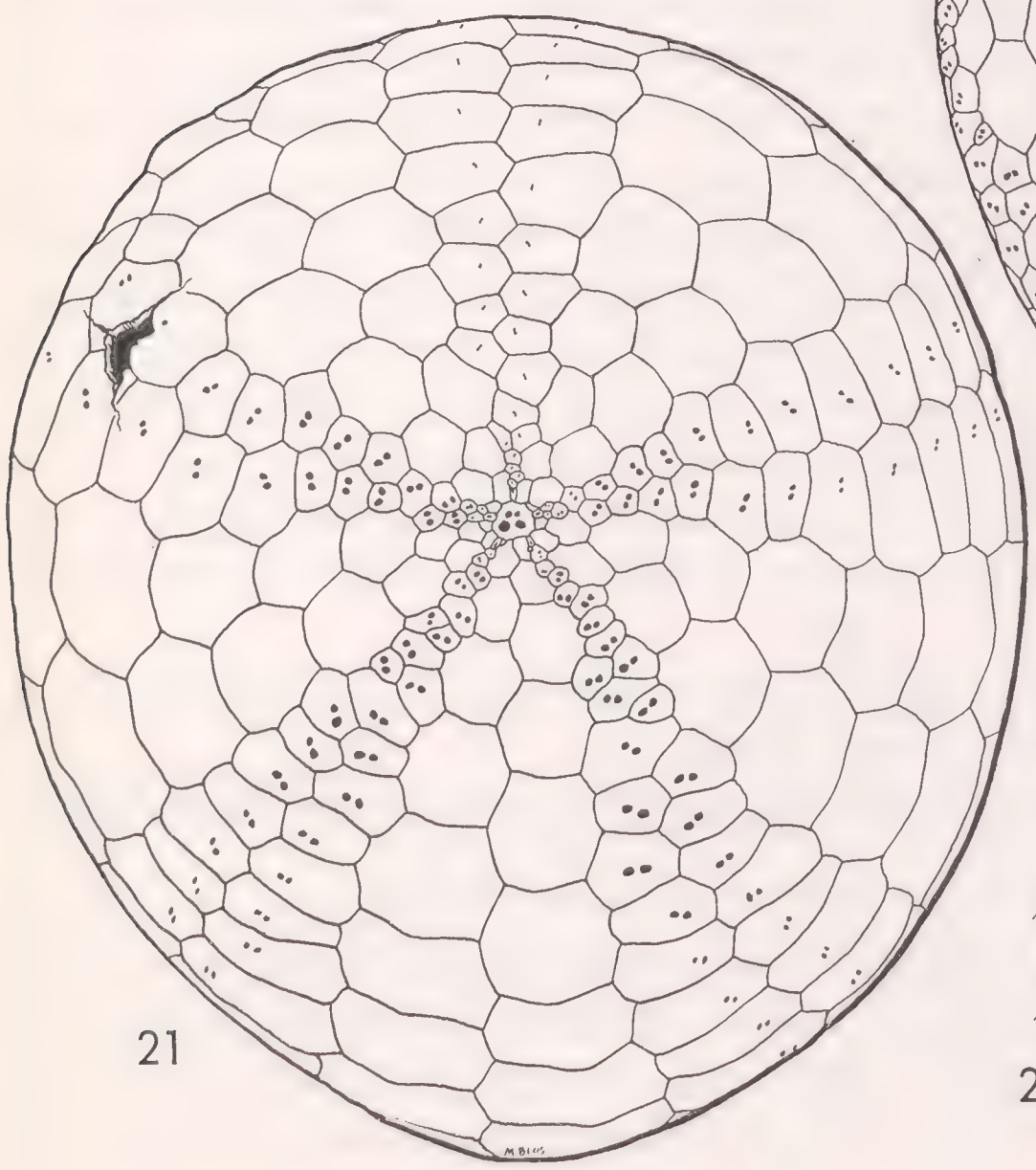

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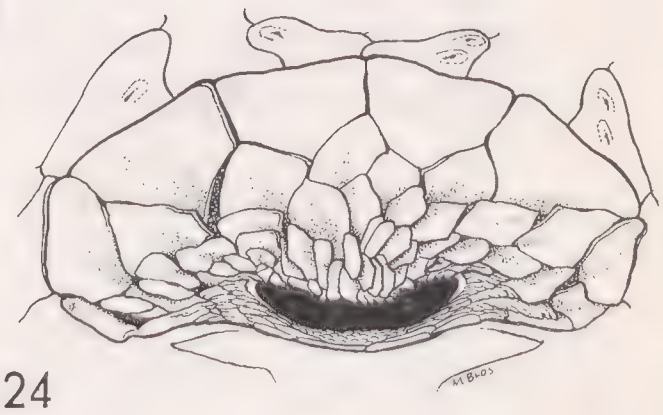

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cluding rare intervening biserial plates (figs. 21, 26), with as many as 15 plates between last paired plates and ocular plate in posterior ambulacra, 11 in anterior paired ambulacra, and 13 in frontal ambulacrum (table 3); ambulacral plates depressed and crowded near peristome forming phyllodes (fig. 22); bivium "naked" on oral surface.

Ambulacral pores not distributed in petals; each pair generally located slightly below middle of plate; pores single and minute in frontal ambulacrum (fig. 21), double and non-conjugate in paired ambulacra except near peristome where they are single (fig. 22).

Podia simple, penicillate on phyllodes.

Interambulacra entirely amphiplacous; plastron amphisternous (fig. 8).

Labrum short and labiate; peristome lunate (fig. 22), depressed; peristomial plates large anteriorly, progressively smaller towards mouth opening (fig. 24).

Apical system ethmolytic (fig. 26), located slightly anterior to test center (fig. 21); genital plates fused, with 4 genital pores; ocular plates distinct (fig. 26); interior of apical system bearing typical "apical apophyse" (Devries, 1960) (fig. 27).

Periproct elongate (fig. 25), low on posterior surface of test, visible on oral side (fig. 22); covered by numerous small plates.

Tubercles weak, perforate, crenulate.

Primary spines moderately long, straight to strongly curved (in peristomial region), tips pointed or asymmetrically spatulate (on plastron) (fig. 28); secondary spines straight to moderately curved (fig. 29).

Fascioles not evident, except for faint ridge which may indicate incipient or obliterated subanal fasciole.

Pedicellariae represented by tridentate and triphyllous forms only, no globiferous or ophicephalous forms; tridentate pedicellariae three-jawed (most common) or four-jawed, both types with long and short forms, both with sculptured surface of ridges and pits and of densely arranged perforations (fig. 30, 31); triphyllous pedicellariae with distinctly serrate blade and base bearing pores which vary in number, shape, and distribution; basal surface of triphyllous pedicellariae either flat or with slight protuberence (fig. 32).

Sphaeridia numerous, on short stalks; distributed along ambulacra to at least sixth pair of post-basicoronal plates.

Color of alcohol preserved specimens, light brown or slightly pinkish.

Distribution. Nasca Ridge, 270-460 meters (HD-73).

Dimensions of types. Dimensions and plate counts are given in table 2 and table 3 for the following specimens: Holotype UCMP 36575 (figs. 21, 23, 26). Paratypes UCMP 36571, 36572 (figs. 22, 27), 36573 (figs. 24, 25), 36574, 36576, 36577, and 36578; British Museum specimen, as yet unnum-

bered; U.S. National Museum specimen, as yet unnumbered; and California Academy of Sciences specimen, as yet unnumbered.

TABLE 2. *Dimensions of the type specimens of* Scrippsechinus fisheri *new species.*

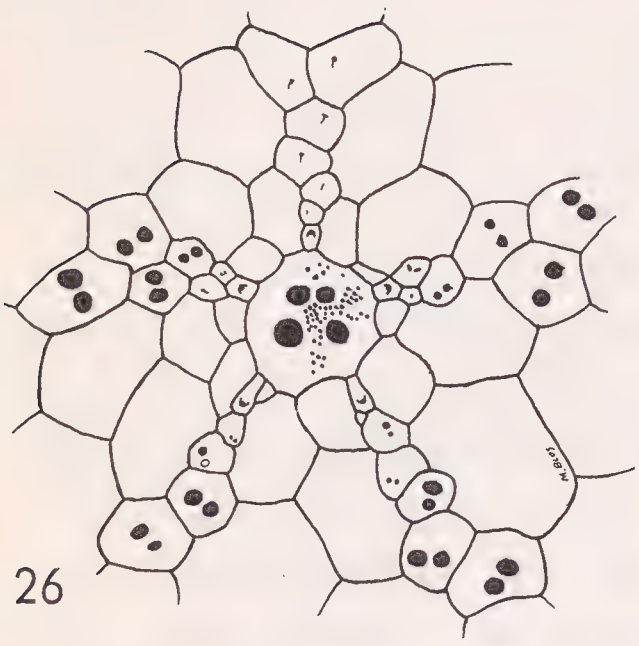
	UCMP										
	36571	36572	36573	36574	36575	36576	36577	36578	CAS	USNM	BMNH
Length (mm.)	54	65	69	72	66	66	59	60	59	59	66
Maximum width (mm.)	52	57	60	62	59	58	50	53	52	51	58
Maximum height (mm.)	37	43	46	46	42	49	38	43	40	42	40

REMARKS. *Scrippsechinus* is assigned to the spatangoid family Asterostomatidae (=Paleopneustidae) because of the amphisternous plastron, compact ethmolytic apical system, differentiated primary spines, non-petaloid ambulacra, and lack of fascioles.

Scrippsechinus differs from all other known asterostomatids, except *Palaeotropus*, by the possession of uniserial ambulacra near the apical system. *Palaeotropus*, however, has far fewer plates in its ambulacra between the first uniserial plate and the ocular plate. Also, in *Palaeotropus*, once uniserial plates appear, there is no reversion to biserial plates adapically as in *Scrippsechinus*. In *Palaeotropus*, ambulacrum I has 5 uniserial plates, ambulacrum II has 1, ambulacrum III has 4, ambulacrum IV has 2, and ambulacrum V has 6 (Mortensen, 1950, p. 295, fig. 205b). In contrast, the number of plates between the first uniserial plate and the ocular plate in *Scrippsechinus fisheri* (table 3) varies in ambulacrum I from 8 to 15, in ambulacrum II from 4 to 10, in ambulacrum III from 5 to 11, in ambulacrum IV from 6 to

TABLE 3. *Number of plates between first uniserial plate and ocular plate (includes some biserial plates) in type specimens of* Scrippsechinus fisheri, *new species.*

	UCMP										
Ambulacrum	36571	36572	36573	36574	36575	36576	36577	36578	CAS	USNM	BMNH
I	11	15	13	10	11	8	?	PRESERVED IN ALCOHOL	?14	8	8
II	7	10	?	8	4	10	?		8	9	5
III	11	11	13	9	8	8	?		10	5	7
IV	9	10	9	6	7	11	?		?	8	7
V	11	15	13	12	11	?13	?		14	11	5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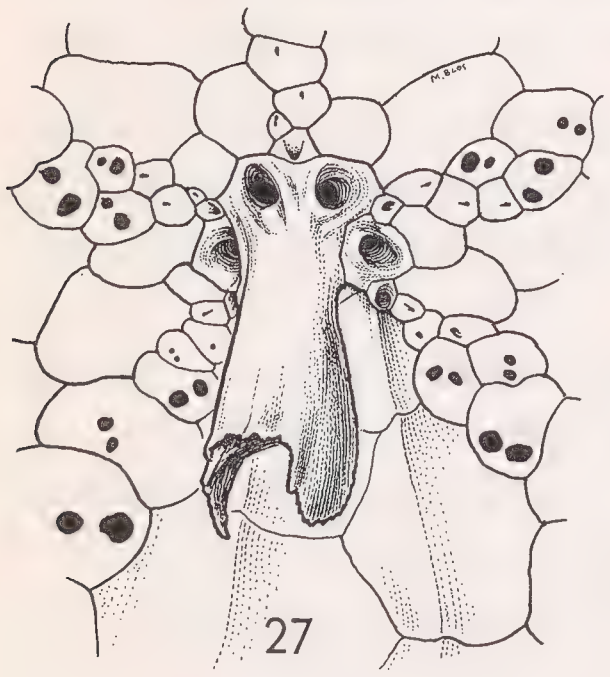
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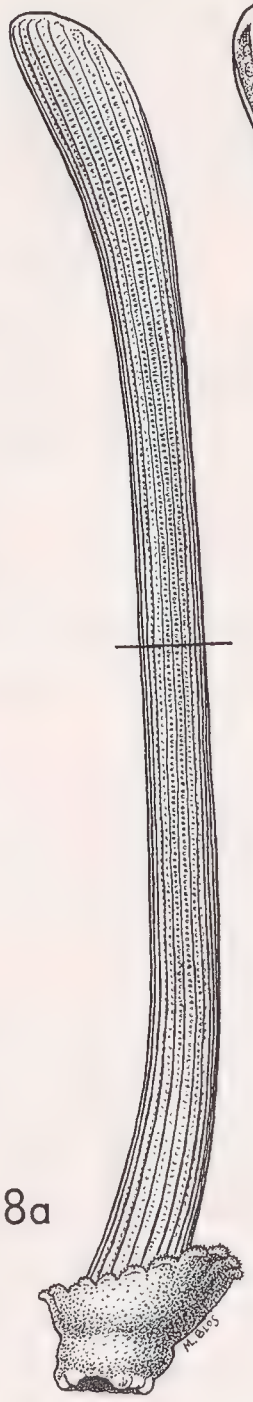
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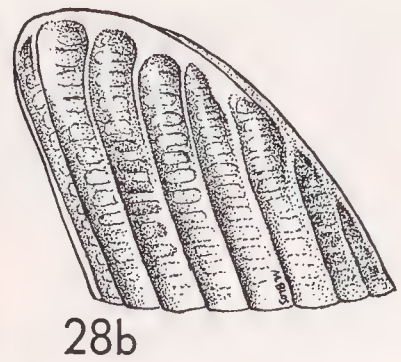
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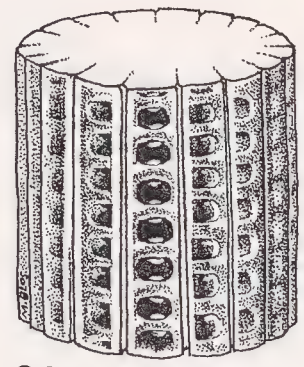
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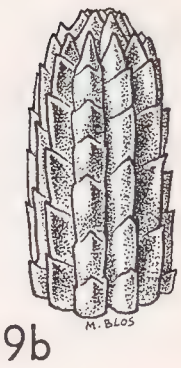
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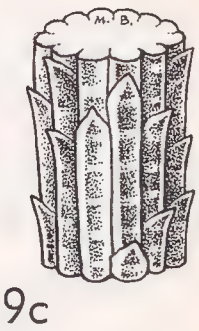
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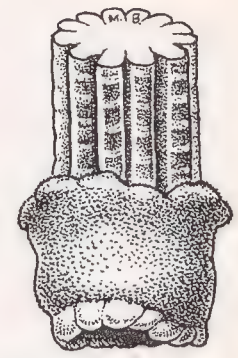
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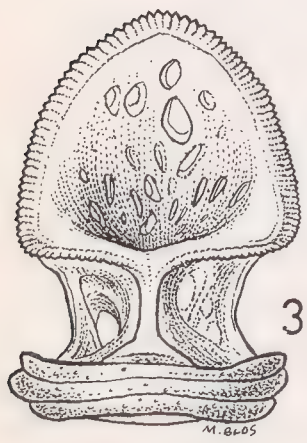
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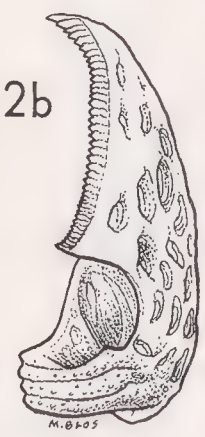
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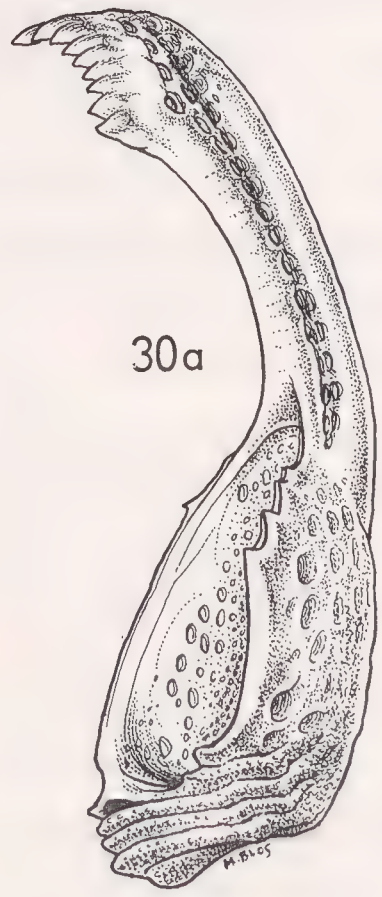
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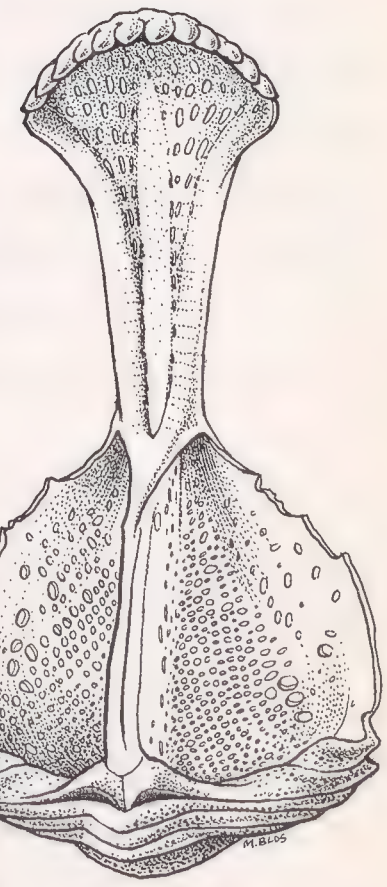
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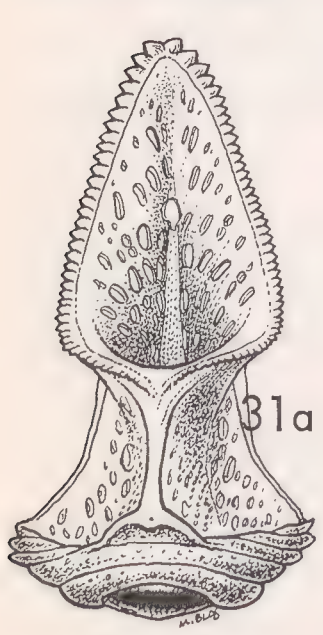
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11, and in ambulacrum V from 5 to 15. In addition, *Palaeotropus* has only two genital pores, a well developed subanal fasciole, a periproct high on the subvertical posterior end, thorny primary spines, and 5 types of pedicellariae.

The completely nonpetaloid nature of the ambulacra would place *Scrippsechinus* in Lambert's subfamily Palaeotropinae to which Mortensen referred the genera *Palaeobrissus, Paleotrema, Palaeotropus,* and *Peripatagus. Palaeobrissus* is the only one of these genera whose ambulacra bear double pores aborally as in *Scrippsechinus. Palaeobrissus,* however, lacks adapical uniserial ambulacra and has a well developed subanal fasciole. Mortensen also doubtfully refers the genera *Cleistechinus* and *Enichester* to the Palaeotropinae. Both of these genera have double pores aborally, but *Cleistechinus* bears a well developed subanal fasciole and two genital pores, while *Enichaster* is a small, depressed form with sub-petaloid ambulacra.

There is no clear trace of a subanal fasciole in *Scrippsechinus,* although a faint ridge is present in the position where a fasciole might be expected. The ridge may indicate an incipient or obliterated fasciole. However, there are no adproctal elongations of the ambulacral plates in the vi-

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FIGURE 26. *Scrippsechinus fisheri,* new genus and new species; exterior view of apical area of holotype UCMP 36575, locality B-6555 (×4.0).

FIGURE 27. *Scrippsechinus fisheri,* new genus and new species; interior view of apical area showing "apical apophyse" of paratype UCMP 36572, locality B-6555 (×5.0).

FIGURE 28. *Scrippsechinus fisheri,* new genus and new species; primary spine, paratype UCMP 36573a, from oral side of ambulacrum V of paratype UCMP 36573, locality B-6555; 28a, entire spine (×20.0); 28b, tip of spine (×87.5); 28c, center of spine (×88.0).

FIGURE 29. *Scrippsechinus fisheri,* new genus and new species; secondary spine, paratype UCMP 36573b, from oral side of ambulacrum I of paratype UCMP 36573, locality B-6555; 29a, entire spine (×35.0); 29b, tip of spine (×133.0); 29c, center of spine (×133.0); 29d, base of spine (×133.0).

FIGURE 30. *Scrippsechinus fisheri,* new genus and new species; large tridentate pedicellaria valve, paratype UCMP 36573c, from oral side of ambulacrum I of paratype UCMP 36573, locality B-6555; 30a, inner surface (×123.0); 30b, lateral view (×123.0).

FIGURE 31. *Scrippsechinus fisheri,* new genus and new species; small tridentate pedicellaria valve, paratype UCMP 36573d, from oral side of ambulacrum I of paratype UCMP 36573, locality B-6555; 31a, inner surface (×205.0); 31b, lateral view (×205.0).

FIGURE 32. *Scrippsechinus fisheri,* new genus and new species; triphyllous pedicellaria valve, paratype UCMP 36573e, from aboral side of interambulacrum V of paratype UCMP 36573, locality B-6-555; 32a, inner surface (×468.0); 32b, lateral view (×468.0).

cinity of the periproct as in *Linopneustes*. Mortensen (1950, p. 211, fig. 158) interpreted these elongations with their enclosed pores as indicative of the presence of a subanal fasciole in the young.

This species is named in honor of Dr. Robert L. Fisher of Scripps Institution of Oceanography, Expedition Leader during the time that sample HD-73 was taken.

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MIOCENE AND PLIOCENE MARINE DIATOMS FROM CALIFORNIA

By

Walter W. Wornardt, Jr.

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MIOCENE AND PLIOCENE MARINE DIATOMS FROM CALIFORNIA*

By

Walter W. Wornardt, Jr.

ABSTRACT: The stratigraphic distribution of diatoms in the upper member of the typical Monterey formation and the Sisquoc formation is recorded and analyzed. About 160 species and varieties of these organisms are systematically classified, described, and figured. Some individuals of the floras studied are planktonic and others are benthonic. They are found to range in age from late Miocene to middle Pliocene. Two diatom floras are recognized from the formations studied. The floras are found in superpositional relationship near Lompoc, California. On the basis of their demonstrated stratigraphic relationships, and their recognition at other localities widely distributed in the Miocene and Pliocene strata of the Pacific Coast, the diatoms appear to be useful for correlating strata throughout the Coast Range area.

* The results reported herein were made possible through National Science Foundation Grant No. 2958-C1, N.S.F. 11083 and continuation G.B.-726.

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Introduction

The West Coast of North America seems to have had environments particularly conducive to the accumulation and preservation of the most extensive marine deposits of diatomaceous sediments in the world. Extensive occurrences of these diatomaceous rocks are especially prevalent throughout the State of California. These strata range in age from Cretaceous to Pleistocene.

Many fossil diatoms from California have been described and figured (Hanna, 1927, 1931, 1932, 1934) and to some extent their local stratigraphic distribution has been tabulated (Lohman, 1938). The geologic age of these diatoms has usually been based upon observable stratigraphic relationships with other well dated megafossils and microfossils.

Diatoms were collected stratigraphically from diatomaceous deposits in three areas: near Monterey, California; the Purisima Hills, north of Lompoc, California; and from an area south of Lompoc, California. In these areas stratigraphic sequences of richly diatomaceous beds attain 100 feet to more than 3,000 feet in thickness and are locally very well exposed.

Acknowledgments

The writer is very grateful to Dr. G Dallas Hanna of the California Academy of Sciences and to Professor Robert M. Kleinpell, University of California, for suggesting, directing, and supervising the investigation and for the assistance furnished through them by the National Science Foundation. Dr. Hanna's type diatom slides, many strewn slides, and unpublished manuscripts were made available for this study. The writer is especially indebted to Dr. Hanna for his instruction in preparing, mounting, and photographing these minute fossil diatoms.

Acknowledgments are likewise due to Dr. Leo G. Hertlein, California Academy of Sciences, for his excellent advice on numerous editorial and systematic problems; the late Ignatius McGuire, Librarian at the California Academy of Sciences, for his diligent assistance in locating numerous obscure publications, many of which were cited under inadequate references; William W. Porter II, geologist, for helpful direction and advice on matters related to the stratigraphy and geology of the Santa Maria Basin; Dr. Friedrich Hustedt, Bremen, Germany; Mr. Richard Ross, British Museum of Natural History, London, England; and Mr. N. Ingram Hendey, British Admiralities, Poole, England, for their valuable advice concerning the systematics of this manuscript; Dr. Taro Kanaya and Dr. Reimer Simonsen for their advice and discussions concerning diatoms; Mrs. Walter Wornardt, Jr., for her typing, drafting, and general assistance in preparing the manuscript; Mr. James Flood of Sisquoc Ranch, and the Johns Manville Company for permis-

sion to visit their properties; the University of California library for the use of numerous foreign journals.

Finally, the writer would like to record his indebtedness to the California Academy of Sciences, at which institution this project was carried out and for the facilities rendered, especially the use of the many hundreds of diatom books and reprints in the Academy library.

Earlier Investigations of the Monterey District

The town of Monterey, California, named in honor of the Count of Monte Rey, the viceroy of New Spain, about 1602, and the first Spanish military establishment in California, is located around 121° W., and 36° 35" N., in Monterey County, about 100 miles south of the City of San Francisco. The Monterey formation, exposed in and about Monterey, which is its type area, has the distinction of being the first formation to be described in California. According to Hanna (1928), the discovery of the white organic shale cropping out at Monterey, California, should be credited to Alexander S. Taylor. This was probably not later than 1852.

The first description of the white organic shale exposed at Monterey, was given by W. P. Blake in 1856 (pp. 180-182), who was a geologist for the Pacific Railway Survey. He cited the principal outcrop as a "white spot on the side of a hill about 2 miles from the center of town." This description is the type designation of the Monterey formation.

The first adequate description of the Monterey formation exposed at Monterey, California, was given by Galliher in 1931. He described a 3160-foot section of Monterey strata and divided it into five lithologic units. Member no. 1, the youngest member, Galliher records as 770 feet of "earthy, diatomaceous, opal silt. Contains approximately 80 percent of silica showing organic structure" (p. 71).

In 1938 R. M. Kleinpell described the "richly organic shale, which outcrops in the hills south and east of the towns of Monterey and Del Monte" as representing the type for the Delmontian stage (p. 131). Within the Delmontian stage, Kleinpell recognized only one time-stratigraphic zone, the *Bolivina obliqua* zone. This zone is essentially the lower substage of this stage and corresponds to the lower half of the overlying diatomite of Galliher's member no. 1. Zones in the upper substage, if any, were left formally unnamed.

This richly organic shale is largely composed of siliceous skeletons of diatoms, silicoflagellates, foraminifers, fish remains, and mollusks, and has been known to paleontologists for the past 110 years. Thomas Brightwell described the first fossil as well as the first diatom, *Triceratium montereyii,* from the Monterey formation in 1853 (p. 251).

In 1854 J. B. Trask recorded five species of "discoid diatoms" from the type Monterey formation but made no attempt to name them. He stated that this valuable "earth" was placed in the hands of the diatomists C. G. Ehrenberg and J. W. Bailey.

These works were followed by papers from a number of diatom students: Brightwell (1858); Greville (1860); Ralfs (1861); Edwards (1873); Grunow (1884); Van Heurck (1880-1885); Rattray (1888, 1889, 1890); De-Toni (1891-1894); P. T. Cleve (1894-1895); Tempère and Peragallo (1907-1915); and A. Schmidt (1874-1961). Each study contained at least one of the following: original description; original drawings; original photomicrographs of diatom species from the diatomaceous earth exposed at Monterey, California.

It is interesting to note that relatively few papers have been published on fossils from the type Monterey formation other than those on diatoms.

In the present study, the writer identified 116 species and varieties of diatoms referable to genera and families, from the upper member of the Monterey formation of the type area. Three samples were collected from a stratigraphic sequence of diatomite exposed in the quarry of the Monterey Products Company 4 miles east of Del Monte on the Monterey-Salinas highway. Four additional samples were collected along the Los Lureles road, east of Monterey and south of Del Monte, California.

Many species occur only in the lowermost portion of the samples, others range through the entire sequence collected, and still others occur only in the upper samples from this member of the Monterey. In the case of certain species, and even genera, proportional representations also vary vertically through the stratigraphic sequence sampled.

Sufficient differences, both qualitative and quantitative, are apparent between assemblages stratigraphically low and high in this sequence to suggest the presence of discrete florules at different horizons within the 770 feet of the upper Monterey diatomite. Sampling, however, has been too local to permit the definition of such florules and of their possible zonules with any assurance at this time. Actually, viewed in its entirety, a fairly high degree of uniformity in the diatom assemblages exists through the stratal sequence, from the base to the uppermost strata of the upper member of the type Monterey.

The diatom flora from the upper member of the type Monterey formation is unlike any other diatom flora described from California. It is therefore difficult to state anything as to the age of the Monterey flora other than its superpositional relationship with the Sharkstooth Hill diatom flora below (from the Temblor formation) of Relizian age (middle Miocene) and the Etchegoin formation of middle Pliocene age above.

The stratigraphic position of the upper member of the type Monterey formation, however, was set forth in detail by Kleinpell (1938). He assigned this sequence of diatomites, a chert and cherty siliceous shale unit below the diatomaceous member of the Monterey formation, as exposed near Monterey, California, to his Delmontian stage and to the Miocene series. He used, as his discipline, the stratigraphic position of this member, with a Mohnian, late Miocene, foraminiferal fauna stratigraphically below and an early Pliocene *Astrodapsis jacalitosensis* megafauna conformably above.

Inasmuch as the diatom assemblages collected from the lower part of the upper diatomite member of the type Monterey formation coincides with and represents Kleinpell's samples numbers 27-33, these diatom assemblages are by definition lower Delmontian. They are equivalent in age to the *Bolivina obliqua* zone, and thus they are clearly older than the early Pliocene beds of the type Jacalitos formation which carry *Astrodapsis jacalitosensis* and age equivalents of them elsewhere in California.

The diatoms herein described from the type Monterey formation, have been exceedingly helpful in determining the stratigraphic relationships of this particular horizon in many parts of California. This same diatom assemblage of common species occurs both in surface outcrops and in well samples throughout California, such as in the Coast Ranges; in the Santa Cruz Mountains; Lompoc; Santa Barbara coast; Palos Verdes Hills; Newport Beach; in the San Joaquin Valley; in Devils Den, Chico Martinez Creek, Belridge, and Modelo Canyon.

Only a few of the 116 diatom species present in the upper type Monterey were truly oceanic forms. Others were planktonic species that were always neritic in habitat; that is to say, near-shore rather than truly oceanic. On the other hand, most of the 116 diatom species were bottom dwellers. Of these, some were vagile benthonic forms, such as many of the species of *Diploneis* and *Navicula.* Other forms were sessile benthonic, such as most of the species of *Arachnoidiscus, Aulacodiscus, Cocconeis,* and *Stictodiscus.*

The Purisima Hills, named for the colonial mission La Purisima, now a state park, are located approximately 34° 38'' N. lat., and 120°, 39'W. long., in Santa Maria district, Santa Barbara County, California. They are bounded on the north by the narrow Los Alamos valley, and the San Antonio valley; on the south by the Santa Ynez River valley.

The geology of the Santa Maria basin has not been treated as extensively in the earlier literature of California as has the Monterey area.

The first record of geologic investigations in the Purisima Hills area was by Thomas Antisell (1856) in the Pacific Railway Reports. He made brief notes concerning the general geologic features of the area.

In 1932 W. W. Porter II, named the Sisquoc formation. This was based upon a "well exposed section on the Sisquoc Ranch, on the southside of Sisquoc River in the Sisquoc Grant" (p. 139). This formation was described as "mostly fine, muddy, silty, friable, gray sandstone" (p. 139). In the same paper he correlated the upper part of the thick diatomite section exposed along the Harris grade in the Purisima Hills, with the Sisquoc formation in its type area on the Sisquoc Ranch.

In their study of the geology and paleontology of the Santa Maria district, California, Woodring and Bramlette (1950) mapped the thick diatomite section along the Harris grade road as the "basin facies" of the Sisquoc formation.

Although the highly fossiliferous Sisquoc formation is well exposed throughout the Santa Maria basin, the paleontology of this formation has not been treated as extensively in the earlier literature of California as has the Monterey formation.

G Dallas Hanna published a very important paper in 1930 on the observations of *Lithodesmium cornigerum* Brun in which he stated that "The species appears to be an excellent marker of one of the zones of the Pliocene diatom-shale in California because it has been abundant on the four occasions when found. It cannot have a long vertical range in the strata and has not thus far been found in Monterey shale" (p. 191).

In Woodring and Bramlette (1950), Lohman identified and listed 18 species and varieties of diatoms from the Sisquoc formation exposed along the Cabrillo Highway (Harris grade road). He also stated that "*Lithodesmium cornigerum* is the most distinctive species. This three-pronged diatom is much like a three-bladed airplane propeller in outline and is not likely to be confused with any other species. It is common in the lower three-quarters of the sampled basin facies of the Sisquoc, occurs in silty diatomaceous strata in the syncline near Sisquoc River, is recorded from the Sisquoc of Graciosa Ridge and the NTU mine, but was not found in the underlying Monterey shale, or in the overlying Foxen mudstone." (p. 36).

In the present study, a total of 71 species and varieties referable to genera and families were obtained from 17 samples collected from the Sisquoc formation exposed along State Highway 1, the Harris grade road, about 2 miles south of Harris and about 7 miles north of Lompoc, California. This sequence was measured initially by Mr. Wents with a plane table and aledaide, and 167 samples were collected and stratigraphically allocated. After careful examination of these samples, 17 samples were selected for detailed study. Subsequently, the writer systematically collected several hundred additional samples from this same measured section and also from the same stratigraphic intervals as those collected by Mr. Wents. Examination of these samples revealed the same diatom assemblages as those found in the earlier collection of Mr. Wents.

The base of the Sisquoc formation is not clearly defined along the Harris grade road because the stratigraphic section crosses the axis of the Purisima anticline to the south. The lower 600 feet of this formation is characterized by porcelaneous shale interbedded with thin cherty layers and some diatomite. The next highest 1500 feet is characterized by light-colored diatomaceous mudstone, interbedded with white laminated diatomite. The next 500 feet is dominately clayey diatomaceous shale and diatomites. The overlying 800 feet is characterized by light-colored diatomaceous shales and diatomites. The upper limit of the Sisquoc formation along the Harris grade road is taken at the uppermost limit of the more massive diatomaceous shales. Actually, the entire section is remarkably uniform from top to bottom, with the massive character of the diatomaceous shale and the scarcity of bedding planes in the upper two-thirds of the section being the most conspicuous features.

The Foxen formation conformably overlies the Sisquoc formation along the Harris grade road. This formation consists of 800 feet of mudstone, clayey siltstone, and thin beds of diatomaceous shales in the basal part.

As is true of the upper member of the type Monterey formation, different species are restricted to separate parts of the Sisquoc formation, whereas other species range throughout it and quantitative representation again emphasized the probable presence of possibly three discrete florules in the Harris grade column.

The lower flora, samples CAS 27295-3 to CAS 27295-57 inclusive, is characterized by the dominance of *Actinocyclus ehrenbergii, Bacteriastrum varians, Coscinodiscus excentricus, C. marginatus, C. lineatus, C. radiatus, Lithodesmium cornigerum, Nitzschia pliocena,* and *Rhaponeis ischaboensis.*

Samples CAS 27295-64 to CAS 27295-102 inclusive are sufficiently similar to permit a designation of a middle flora. *Coscinodiscus asteromphalus, C. obscurus, Nitzschia pliocena, Biddulphia aurita,* and *Hemidiscus simplicissimus* make their first appearance, while *Lithodesmium cornigerum* and *Rhaponeis ischaboensis* become rare near the upper limit of this flora.

The diatom assemblages found in samples CAS 27295-113 to CAS 27295-154 inclusive compose the upper flora in this stratigraphic section along the Harris grade. Actually, sample CAS 27295-154, the uppermost sample in this flora, was obtained from the Foxen formation. *Lithodesmium cornigerum* and *Nitzschia ischaboensis* disappear near the uppermost portion of this flora. *Arachnoidiscus ehrenbergii, Asteromphalus arachne, Coscinodiscus obscurus, C. lineatus* var. *convexus,* and *C. robustus* var. *herculus,* make their first appearance in this upper flora.

Porter (1932) stated that the Pliocene age of the Sisquoc formation was based upon the identifications of fossil mollusks from this area by Mrs.

Castle. In her unpublished report to Porter, the lower type Sisquoc was determined as "Lower Jacalitos, lower Pliocene." She stated that the upper Sisquoc formation contains mollusks which seem to "correlate with Arnold's lowest Fernando horizon of the Santa Maria area. The horizon is Pliocene, probably Jacalitos (lower Etchegoin)," In the conclusion of the same report, she also stated that the lower part of the Sisquoc section "is lower in the Pliocene than any Pliocene so far known in the Santa Maria Basin."

Also within the upper few hundred feet of the Sisquoc formation is a molluscan assemblage which they considered middle Pliocene and correlated with "at least part of the Etchegoin Formation." A few megafossils from the middle part of the basin facies have "Pliocene affinities" according to Woodring and Bramlette (1950, p. 101). There have been no megafossils of definite Miocene age reported from the Sisquoc formation in the Purisima Hills.

The age of the Sisquoc formation is therefore based in part on the superpositional relationship with the overlying Foxen formation of middle Pliocene age and the underlying upper member of the Monterey formation of late Miocene age.

It is also based in part on the megafossils from the middle part of the Sisquoc formation, having Pliocene affinities and lower Jacalitos, "lower Pliocene" megafossils, from the lower part of the type Sisquoc formation.

The diatoms from the Sisquoc formation make up a very distinct flora. It is difficult to state the precise age of the Sisquoc formation from the diatoms themselves. Its general age, however, can be based on its superpositional relationships with the typical Monterey diatom flora below, from the upper Monterey formation of Delmontian age (late Miocene) and the San Joaquin formation, late Pliocene age above. It should be noted that the San Joaquin formation stratigraphically overlies the Etchegoin formation in the San Joaquin Valley, and the megafossil fauna in the upper part of the type Sisquoc formation was considered a correlative at least in part of the Etchegoin formation.

The diatoms herein described from the Sisquoc formation and lower part of the Foxen formation have been exceedingly helpful in determining the stratigraphic relationships of these particular horizons in many parts of California.

The characteristic diatom assemblage seems to be sufficiently distinct for recognition throughout much of the Santa Maria basin. Additional samples have been examined to warrant the belief that the flora is recognizable for considerable distances, such as from: Pt. Reyes peninsula, Santa Cruz Mountains, Lompoc, Goleta Point, Kettleman Hills, and North Belridge Field.

In contrast to the Monterey diatom flora, the forms from the lower and middle parts of the Sisquoc formation exposed along Harris grade are main-

ly planktonic species. These diatoms constitute almost the entire flora found in the lower 2300 feet of section CAS 27295-3 to CAS 27295-102 inclusive. These planktonic diatoms decrease in number of species beginning in sample CAS 27295-113 and continue to decrease upward through the Harris grade sequence. They are replaced by an increasing number of bottom dwelling forms. The later are most numerous in the upper 1200 feet of the Sisquoc formation and lower Foxen formation.

A considerable number of these bottom dwellers are sessile benthonic and vagile benthonic forms, such as *Arachnoidiscus, Cocconeis, Triceratium, Navicula,* and *Diploneis*. Other littoral forms are also common, such as *Coscinodiscus robustus* and several species of *Stephanopyxis*.

Two diatomaceous samples were collected from the stratigraphically highest outcrop of diatomite in the main quarry of the Johns Manville plant in Lompoc, California. Here the stratigraphic sequence is continuous and exhibits a dip of about 5 degrees toward the north. In this sequence the Sisquoc formation, in typical brownish massive lithologic expression, conformably overlies the upper most and distinctively white, punky diatomite so characteristic of the upper member of the type Monterey formation.

Each of the two samples collected from the quarry at Lompoc yielded different diatom assemblages. The uppermost diatomite assemblage is sufficiently similar to the lower flora of the Sisquoc formation as it occurs along the Harris grade to permit a designation of lower Sisquoc flora. Similarly, the lower diatomite assemblage is sufficiently similar to the Monterey flora of the type Monterey formation, Monterey, California, to permit a designation of upper Monterey flora.

When the Harris grade Sisquoc flora is compared with the upper member of the type Monterey flora, the differences between the two floras are striking. Then if we consider the difference in floral content between Sisquoc flora of the Harris grade and the upper Monterey flora of the Lompoc area, again we find a striking difference between floras. Finally, if we consider the similarity in specific floral content, of the Harris grade and the Sisquoc of the Lompoc area (which directly overlies the upper Monterey flora), the similarities are just as striking.

It is thus possible to evaluate to some extent at least the differences and similarities in the distribution of diatom species and of diatom florules in the upper member of the Monterey and Sisquoc formation both stratigraphically and regionally.

Diatoms

In view of these geologic age determinations and correlations as summarized above, the marked differences in diatom floras from the upper member of the type Monterey formation and from the Sisquoc formation respec-

tively, take on added significance for purposes of determining the geologic age of diatom floras and diatomaceous strata. In the case of the upper type Monterey diatom flora, its containing stratum immediately underlies sandstones of early Pliocene age. In the case of the Sisquoc diatom flora, its containing strata are lateral equivalents of early and middle Pliocene sandstones. That these differences between the two diatom floras studied are of geologic significance is then independently checked by the direct evidence from the stratigraphic relationships between essentially the same two diatom floras in the Lompoc area, where two samples of the Monterey flora (CAS 1736) occur in strata directly overlain by beds carrying the Sisquoc flora (CAS 27730) of the Sisquoc formation.

Additional examples may be cited in passing in which still other and different diatom floras are shown to be of comparably different geologic age. They are: those from the upper Temblor formation of Sharktooth Hill in Kern County, California, which are very different both from the upper Monterey and from the Sisquoc floras and are, through other lines of evidence, known to be of middle Miocene age; and those from the Etchegoin formation of the Kettleman Hills, which are again different and known to be of middle or late Pliocene age. It is probably significant to note further that the Etchegoin floras in reference have many more diatom species in common with the Sisquoc than with the Monterey floras, and that the Temblor flora in reference has many more species in common with the Monterey than with the Sisquoc flora.

Finally, floras very comparable to those of the upper type Monterey have been collected from the upper Modelo formation of Girard (on the northern slopes of the Santa Monica Mountains), from the Malaga mudstone member of the Monterey formation in the Palos Verdes Hills, and from the lower Belridge diatomite of the Monterey formation in Chico Martinez Creek. All of these stratigraphic occurrences are altogether in keeping with the age correlations to be inferred from these very closely related diatom floras, according to all known lines of evidence other than those furnished directly by the diatoms themselves.

All these occurrences corroborate the association of the characteristic Delmontian diatom floras as found in the upper member of the type Monterey, with the foraminiferal fauna of the Delmontian stage as found elsewhere.

Insofar as these relationships between diatom floras and foraminiferal faunas are not only true in the Monterey area, but are generally true where the two are found elsewhere in the Coast ranges, it seems likely that the many other areas where these diatom floras are found unassociated with other fossils (foraminifers or other fossils, as the case may be), that the containing strata may be considered to be Delmontian age, even though neither fossil foraminifers nor megafossils may be locally present.

The distinctive diatom flora of the Sisquoc formation from the Harris

grade sequence has also been found in other areas widely deployed in the California Coast ranges, namely, Point Reyes, the Taft area, Naples, of the Santa Barbara coast, and especially the Santa Maria basin, other than the Harris or Lompoc areas. The rocks in these areas stratigraphically overlie rocks of demonstrable Delmontian age. On the basis of the direct evidence from the diatom floras, the strata as well as the flora must be of that age or younger.

In summary, comparison of the diatoms in both the Monterey and the Sisquoc areas, plus direct superposition of the same floras in the Lompoc area, point directly to the relative age determinations of the two floras, respectively, that are entirely in keeping with age determinations and correlations based upon other lines of evidence. It strongly indicates that diatoms and diatom floras evolved according to the same principles as other life and that they may be used to correlate strata in a comparable manner. These should aid significantly, especially where other fossils, larger marine invertebrates, foraminifers, and even mammals, are rare or occur only sporadically as is so often true in many local stratigraphic columns throughout the Coast ranges and elsewhere.

Descriptions of California Academy of Sciences Localities

Locality 866 (CAS). Diatomaceous shale. Four miles east of Del Monte on road to Salinas, California, at plant for preparation of diatomaceous earth. Soft, pure samples some from near top of deposit. Strata dip steeply to west and strike almost north. G D. Hanna, collector, November, 1923.

Locality 1274 (CAS). Impure shale from the base of the Monterey section very close to granite contact. The locality is on the road from Salinas-Monterey Highway to Tassajara Springs and near top of hill, 3.7 miles north of Carmel Valley. The dip is almost flat. G D. Hanna and W. M. Grant, collectors, November, 1927.

Locality 1275 (CAS). On same road as 1274 and 0.8 mile north and higher in section. Dip about 5 degrees.

Locality 1276 (CAS). On same road as 1274 and 0.07 mile north of 1275. Dip is 10 degrees.

Locality 1277 (CAS). On same road as 1274 and 0.2 mile north of 1276. Dip is 45 degrees.

Locality 1278 (CAS). On same road as 1274 and 0.7 mile north of 1277. Dip is vertical.

Locality 27295 (CAS). Diatomite. A long series of samples from the highway grade over Purisima Hills from Harris to Lompoc, Santa Barbara County, California. J. H. Wents, collector, 1931. Pliocene. The samples

extend from the axis of the anticline upward in the section 4250 feet. The upper three samples contain foraminifera. The section was studied in detail by G D. Hanna (report in files of the Department of Geology of the California Academy of Sciences). Numbers 1-167 were originally put on the bags and are now sub-numbers. Reference in the present paper is to 19 samples located stratigraphically with reference to the axis of the anticline mentioned under locality 27295 (CAS) as datum, as follows:

3 (CAS). Buff diatomite, at base of section on south limb of Purisima anticline.

7 (CAS). Light buff impure diatomite, at base of section, south of Purisima anticline in Todos Santos member of Sisquoc formation.

25 (CAS). Whitish diatomite, 650 feet above crest of Purisima anticline.

29 (CAS). Buff diatomite, 760 feet above crest of Purisima anticline.

38 (CAS). Buff diatomite, 890 feet above crest of Purisima anticline.

49 (CAS). Buff diatomite, 1016 feet above crest of Purisima anticline.

57 (CAS). Buff diatomite, 1418 feet above crest of Purisima anticline.

64 (CAS). Buff diatomite, 1570 feet above crest of Purisima anticline.

73 (CAS). Buff diatomite, 1750 feet above crest of Purisima anticline.

83 (CAS). Buff diatomite, 1800 feet above crest of Purisima anticline.

94 (CAS). Buff diatomite, 2075 feet above crest of Purisima anticline.

102 (CAS). Buff diatomite, 2280 feet above crest of Purisima anticline.

113 (CAS). Buff diatomite, 2445 feet above crest of Purisima anticline.

122 (CAS). Buff diatomite, 2760 feet above crest of Purisima anticline.

129 (CAS). Buff, impure, ashy diatomite, 3105 feet above crest of Purisima anticline.

135 (CAS). Buff, impure, ashy diatomite, 3250 feet above crest of Purisima anticline.

154 (CAS). Buff, impure diatomite with impressions of foraminifers 3525 feet above crest of Purisima anticline.

155 (CAS). Buff, silty shale, foraminifers abundant, 3600 feet above crest of Purisima anticline.

162 (CAS). Buff, ashy shale, 4070 feet above crest of Purisima anticline.

Locality 1736 (CAS). Diatomite from extreme top of deposits in Celtite quarry 2 miles south of Lompoc, California. Sample taken from top of hill northwest of the plant and in axis of the syncline. W. W . Wornardt, Jr., collector, 1962.

Locality 27730 (CAS). Diatomite. Lompoc, Santa Barbara County, California. Sample from highest part of exposure. Pliocene. W. W. Wornardt, Jr., collector, 1962.

SYSTEMATIC TREATMENT

Kingdom PLANTAE
Division CHRYSOPHYCOPHYTA
Phylum CHRYSOPHYCEAE
Class BACILLARIOPHYCEAE [1] Fritsch [2], 1935
Order BACILLARIALES [3] Schütt [4], 1896
Suborder Coscinodiscineae Hendey, 1964
Family Coscinodiscaceae Kützing [5], 1844
Subfamily Melosiroideae Kützing [6], 1844

Genus **Melosira** Agardh, 1824

Melosira clavigera Grunow.

(Figures 1, 2.)

Melosira clavigera Grunow, *in* Schmidt, 1876, pl. 74, figs. 13-15. Hanna, 1951, p. 284, fig. 3 (1).
"M. ?Clavigera Grun." *in* Van Heurck, 1882, pl. 91, figs. 1,2. "Monterey et San Francisco."

Geologic range. Late Miocene to late Pliocene.(7)

Melosira sulcata (Ehrenberg) Kützing.

Gaillonella sulcata Ehrenberg, 1838, p. 170, pl. 21, fig. 5.
Melosira sulcata (Ehrenberg) Kützing, 1844, p. 55, pl. 2, fig. 7. Hustedt, 1928, p. 276, figs. 118, 119.

Geologic range. Late Eocene to Recent.

Ecology. Reported to be temperate, subtropical, and sometimes found in neritic plankton. "A true bottom form...," according to Hendey (1964, p. 73).

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1 Rabenhorst was the first person to raise the diatoms to the level of class as Diatomphyceae.

2 Fritsch, 1935, pp. 7, 564. West (1904, p. 273), first used the name Bacillarieae but as a class, while Engler and Gilg (1919, p. 13) first used the name Bacillariophyta but used it as a division.

3 Some may prefer Diatomales as the order name (Webster's New International Dictionary, 1951, p. 198).

4 Schütt, 1896, pp. v, 31, as a subclass; new status Hendey, 1937, pp. 200, 202. Nitzsch (1817, p. 56) used Bazillarien as a "group" name for all diatoms known to him. Bory de Saint Vincent (1822, p. 127) used Bacillariées as a family grouping.

5 Kützing, 1844, p. 130, as family Coscinodisceae; change of spelling, De-Toni, 1890, pp. 894, 915.

6 Kützing, 1844, pp. 32, 48, as a family Melosireae; new status and change of spelling, Hustedt, 1930, pp. 55, 82.

7 Geologic range. This refers to the presently known geologic range of the particular species as recorded from the west coast of North America, California to Alaska.

Genus **Hyalodiscus** Ehrenberg, 1845

Hyalodiscus valens Schmidt.

(Figure 3.)

Hyalodiscus valens Schmidt, 1888, pl. 140, fig. 1.

Geologic range. Late Miocene.

Subfamily Skeletonemoideae Schütt, 1896 [8, 9]

Genus **Endictya** Ehrenberg, 1845

Endictya oceanica Ehrenberg.

(Figures 5-7.)

Endictya oceanica Ehrenberg, 1845, p. 76. Ehrenberg, 1854, pl. 35, gr. 18, figs. 6, 7. Schmidt, 1886, pl. 65, figs. 10, 12, 13. Hustedt, 1928, p. 297-299, fig. 136. Lohman, 1941, p. 66, pl. 12, fig. 3. A. Cleve-Euler, 1951, p. 36, figs. 37 a-e. Hendey, 1957, p. 41, pl. 6, fig. 5. Not *Endictya oceanica* Ehrenberg, of Long, Fuge, and Smith, 1946, p. 106.

Coscinodiscus divisus Grunow. A. Cleve-Euler, p. 58, figs. 80, c, d.

"*Orthosira oceanica (Endictya oceanica)*, Ehr." Brightwell, 1860, Quart. Jour. Micr. Sci., vol. 8, p. 96, pl. 6, fig. 14 cited as fig. 16.

Geologic range. Late Miocene.

Remarks. Valve surface slightly convex, areolation coarse, approximately the same size over the entire valve surface, about 2½ to 3 areolae in 0.01 mm. Areolation is not unlike the pattern of *Coscinodiscus excentricus* Ehrenberg. The border appears as a wide, dark area in photomicrographs. A mill-like edge on border encircles valve.

Endictya species.

(Figure 4.)

Geologic range. Late Miocene.

Remarks. Valves convex. Areolation very coarse, from 2½ to 3 areolae in the central region, continuing nearly equal in size to the margin. The areolae appear rounded over the entire surface. The areolation pattern is not unlike *Coscinodiscus lineatus* Ehrenberg. It has a distinctive elevated rim, a mill-like network of protrusions, about 0.01 mm. high. From this rim the valve turns vertically downward and continues for about 40-50 microns. The areolae follow the valve surface as it turns vertically downward with about 2½ or 3 areolae in 0.01 mm.

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8 Schütt, 1896, p. 55, as a subtribe Skeletoneminae.

9 Hustedt, 1930, p. 55, new status and change of spelling.

Genus **Stephanopyxis** Ehrenberg, 1845

Stephanopyxis antiqua Pantocsek.

(Figure 8.)

Stephanopyxis antiqua PANTOCSEK, 1883, p. 96, pl. 19, fig. 280.

GEOLOGIC RANGE. Middle Pliocene.

REMARKS. This species is characterized by a very convex valve "in lineas excentricas dispositae," according to Pantocsek (1893, p. 96).

Stephanopyxis lineata (Ehrenberg) Forti.

(Figures 9-11.)

Stephanodiscus ?lineatus (=Peristephania lin.?) EHRENBERG, 1854, pl. 33, gr. 13, fig. 22.

Stephanopyxis lineata (Ehrenberg), FORTI, 1913, p. 1547 (p. 13), pl. 1, figs. 21, 23; pl. 2, fig. 3. LOHMAN, 1948, p. 158, pl. 6, fig. 3.

GEOLOGIC RANGE. Middle Miocene to late Miocene.

REMARKS. Distinguished by the high marginal spines near the border and the linear pattern of the areolae.

Stephanopyxis turris var. **cylindrus** Grunow.

Stephanopyxis turris var. *cyclindrus* GRUNOW, 1884, p. 35 (p. 87). SCHMIDT, 1888, pl. 130, fig. 25 no name.

"Stephanopyxis appendiculata var.?" *in* SCHMIDT, 1888, pl. 130, fig. 34,

GEOLOGIC RANGE. Late Miocene to late Pliocene.

Stephanopyxis turris var. **polaris** Grunow.

Stephanopyxis turris var. *polaris* GRUNOW, 1884, p. 37 (p. 89), pl. 5 (pl. E), figs. 19, 23, 25. HUSTEDT, 1928, p. 306, fig. 144. SCHMIDT, 1878, pl. 58, fig. 9.

GEOLOGIC RANGE. Early Pliocene.

ECOLOGY. The typical species is a pelagic form, frequent in temperate seas and rare in polar waters, according to Hendey (1937, p. 237).

REMARKS. The present identification is based upon the illustration in Schmidt's Atlas. This species, when observed under a proper adjustment of the microscope, so the valve is properly in focus, compares favorably with the diatom on pl. 58, fig. 9 of Schmidt, 1878.

Stephanopyxis appendiculata Ehrenberg.

(Figures 12, 13.)

Pyxidicula appendiculata EHRENBERG, 1844, pp. 85, 264.

Stephanopyxis appendiculata EHRENBERG, 1854, pl. 18, fig. 4. MANN, 1907, pp. 244, 245.

Coscinodiscus antiqua Pantocsek, REINHOLD, 1937, p. 114, pl. 15, fig. 13.

Geologic range. Late Miocene.

Remarks. This species is distinguished by its conical valve, coarse areolae, radially arranged in a trilinear pattern and by the narrow border. The small spines at the crest of the valve can best be seen in girdle view.

Subfamily Coscinodiscoideae Schütt, 1896 [10, 11]

Genus **Coscinodiscus** Ehrenberg, 1838

Coscinodiscus argus Ehrenberg.

Coscinodiscus argus Ehrenberg, 1838, p. 129. Hustedt, 1928, p. 422, fig. 226. Lohman, 1941, p. 70, pl. 13, figs. 1, 3.
Coscinodiscus heteroporus Ehrenberg, 1844, p. 265 [1845].
Coscinodiscus woodwardii Schmidt, 1878, p. 61, figs. 2, 3.

Figure 1. *Melosira clavigera* Grunow. Hypotype no. 3121 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.0672 mm.

Figure 2. *Melosira clavigera* Grunow. Hypotype no. 3121a (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.0872 mm.

Figure 3. *Hyalodiscus valens* Schmidt. Hypotype no. 3897 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.1695 mm.

Figure 4. *Endictya* new species. Hypotype no. 3898 (CAS), locality 866 (CAS), Monterey, California. Diameter 0.0910 mm.

Figure 5. *Endictya oceanica* Ehrenberg. Hypotype no. 3899 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.1020 mm.

Figure 6. *Endictya oceanica* Ehrenberg. Hypotype no. 3900 (CAS), from locality 1277 (CAS), Monterey, California.

Figure 7. *Endictya oceanica* Ehrenberg. Hypotype no. 3901 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.1100 mm.

Figure 8. *Stephanopyxis antiqua* Pantocsek. Hypotype no. 3902 (CAS), from locality 27295-155 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Diameter 0.0190 mm.

Figure 9. *Stephanopyxis lineata* Ehrenberg. Hypotype no. 3903 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.1102 mm.

Figure 10. *Stephanopyxis lineata* Ehrenberg. Hypotype no. 3904 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.1270 mm.

Figure 11. *Stephanopyxis lineata* Ehrenberg. Hypotype no. 3905 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.1070 mm.

Figure 12. *Stephanopyxis appendiculata* Ehrenberg. Hypotype no. 3906 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.0820 mm.

Figure 13. *Stephanopyxis appendiculata* Ehrenberg. Hypotype no. 3907 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.0770 mm.

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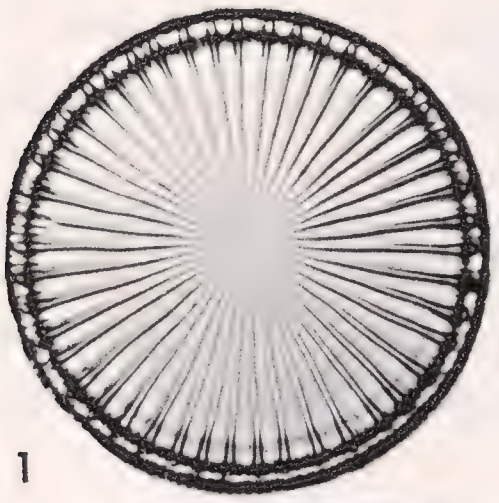
10 Schütt, 1896, pp. 55, 64, as a subtribe Coscinodiscinae.

11 Kolbe, 1927, pp. 29, 31, new status and change of spelling.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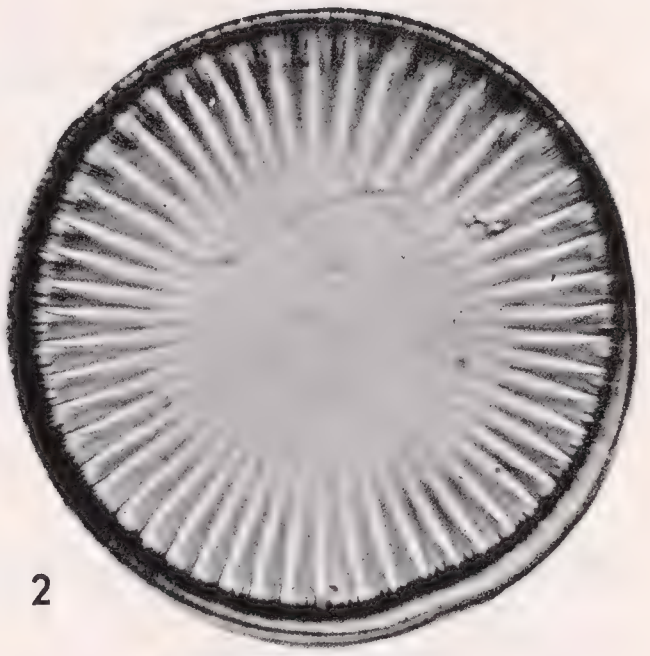
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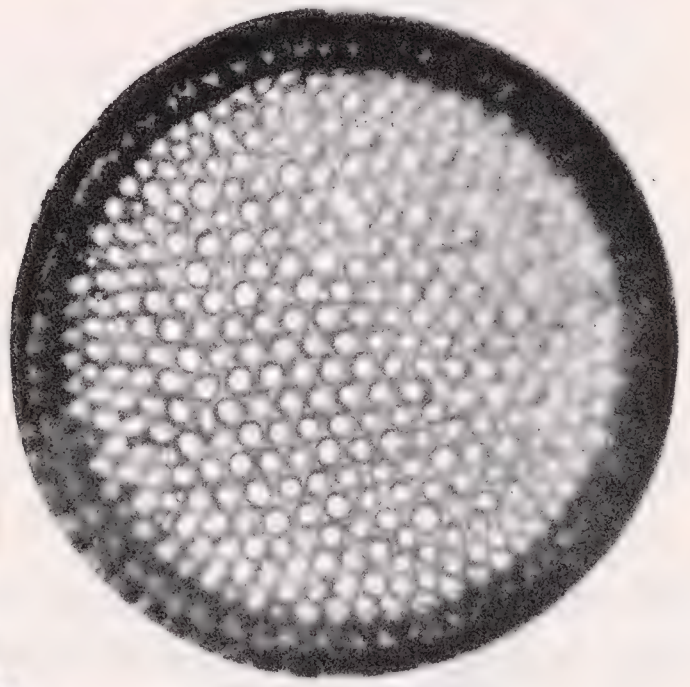
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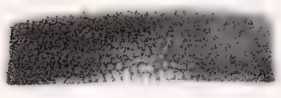
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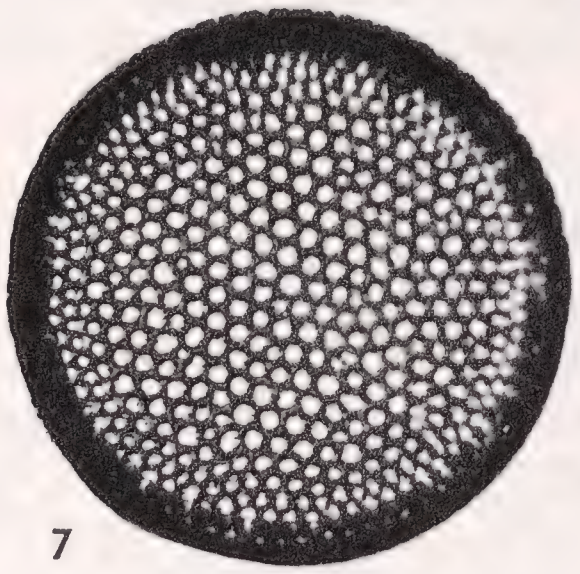
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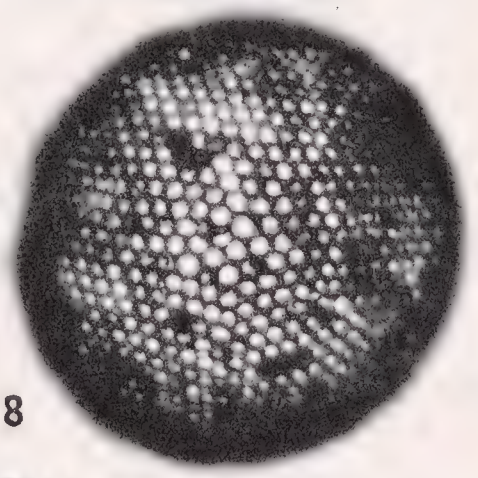
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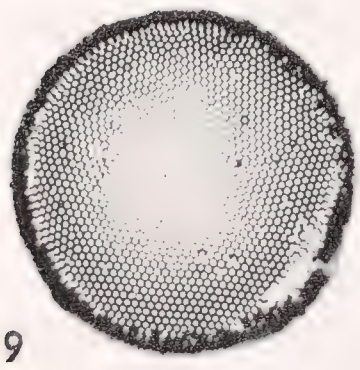
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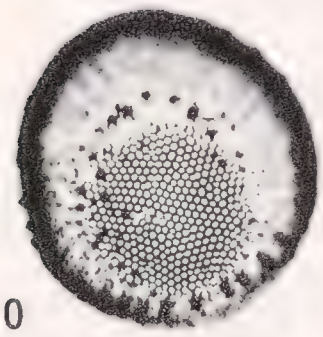
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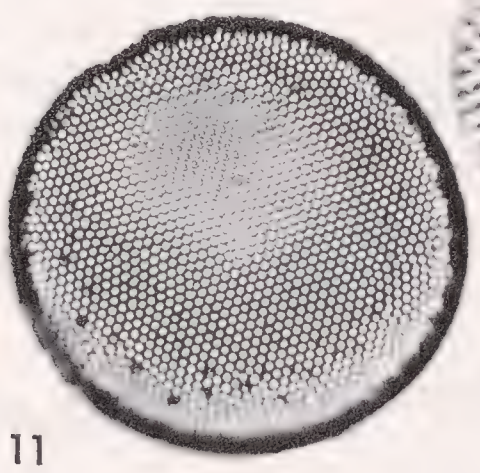
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Geologic range. Late Eocene to Recent.

Ecology. This species lives in warm marine water in the neritic zone, according to Lohman (1941).

Kolbe (1954, p. 28) adds confirmation to Hustedt's assumption that *C. argus* Ehrenberg is a littoral species.

Remarks. This species is distinguished from *C. radiatus* Ehrenberg in having its areolae increase in diameter toward the border; from *C. obscurus* Schmidt in lacking interstitial meshes.

Coscinodiscus antiquus (Grunow) Rattray.

(Figure 23.)

Coscinodiscus (exentricus, var.?) *antiquus* Grunow, 1884, p. 84, pl. iv (D), fig. 24.
Coscinodiscus antiquus (Grunow) Rattray, 1889, p. 461 (13).

Geologic range. Late Miocene to Recent.

Remarks. This species differs from the typical *Coscinodiscus excentricus* in possessing coarser areolae and a distinct border.

Coscinodiscus asteromphalus Ehrenberg.

(Figures 14-18.)

Coscinodiscus asteromphalus Ehrenberg, 1844, p. 77 [1845]. Ehrenberg, 1854, pl. 18, fig. 45; pl. 33, group 15, fig. 7. Schmidt, 1878, pl. 63, fig. 12; 1888, pl. 113, figs. 22, 23.

Geologic range. Late Miocene to Recent.

Ecology. Hendey (1937, p. 244) describes this species as "a neritic diatom, favouring a fairly high salinity." He also states that it "was observed only in material from the Pacific Ocean."

"A pelagic plankton species with a world wide distribution," according to Hendey (1964, p. 78).

Coscinodiscus asteromphalus var. **omphalantha** (Ehrenberg) Grunow.

(Figure 19.)

Coscinodiscus omphalanthus, Ehrenberg, 1844, p. 266.
Coscinodiscus asteromphalus var. *omphalantha* (Ehrenberg) Grunow, 1884, p. 78. Rattray, 1890, p. 549 (101). Lohman, 1938, pl. 20, fig. 2.

Geologic range. Late Miocene to late Pliocene.

Coscinodiscus concavus Gregory.

(Figure 20.)

Coscinodiscus concavus Gregory, 1857, p. 500, pl. 10, fig. 47. Schmidt, 1878, pl. 62, fig. 8.

GEOLOGIC RANGE. Late Miocene.

REMARKS. Coarse areolae, 2½ to 3 in 0.01 mm. Border distinct.

Coscinodiscus confusus Rattray.

(Figure 21.)

Coscinodiscus confusus RATTRAY, 1890, p. 451 (p. 3). SCHMIDT, 1877, pl. 64, fig. 15 [no name].

GEOLOGIC RANGE. Late Miocene.

ECOLOGY. This species has been reported previously only from Campeachy Bay.

Coscinodiscus curvatulus Grunow.

Coscinodiscus curvatulus GRUNOW, *in* Schmidt, 1878, pl. 57, fig. 33. RATTRAY, 1890, p. 486. HUSTEDT, 1928, p. 406, fig. 214. LOHMAN, 1941, p. 74, pl. 15, fig. 8.

GEOLOGIC RANGE. Late Miocene to Recent.

ECOLOGY. According to Hendey (1937, p. 252) this oceanic species is widely distributed in the temperate seas. Later Hendey (1964, p. 81) stated that this is 'A neritic boreal species."

Lohman (1941, p. 74) states that this oceanic planktonic species occurs more abundantly in cold northern waters, but according to Lebour (1930, p. 46), this is a neritic species.

Coscinodiscus curvatulus var. **minor** (Ehrenberg) Grunow.

(Figure 22.)

Coscinodiscus minor EHRENBERG, 1838, p. 129, pl. 12e [1840].
Coscinodiscus curvatulus var. *minor* (Ehrenberg) GRUNOW, 1884, p. 83, pl. 4(d), figs. 8-10. RATTRAY, 1890, p. 487. HUSTEDT, 1928, p. 409, fig. 217. LOHMAN, 1941, p. 75, pl. 16, fig. 3.

GEOLOGIC RANGE. Late Miocene.

ECOLOGY. Typically found pelagic in all seas, usually with *C. excentricus* and usually more abundant in colder waters, according to Lohman (1941, p. 75).

REMARKS. The curved fascicles immediately distinguish this variety of *C. curvatulus* from the typical form.

Coscinodiscus excentricus Ehrenberg.

Coscinodiscus eccentricus EHRENBERG, 1838, p. 146 [1841]. EHRENBERG, 1841, pp. 322, 323, 371, pl. 3, gr. 3, fig. 5. SMITH, 1853, p. 23, pl. 3, figs. 38, 38´, 38b, 38d.

Coscinodiscus excentricus (Ehrenberg) Schmidt, 1886, pl. 58, figs. 46-49. Van Heurck, 1881, pl. 130, figs. 4, 7, 8. Rattray, 1890, p. 461 (p. 13). Mann, 1907, p. 251. Hanna, 1927, p. 111, pl. 17, fig. 8. Hustedt, 1928, p. 388, fig. 201. Lohman, 1938, p. 82, pl. 20, fig. 5; pl. 21, fig. 5. Lohman, 1941, p. 67, pl. 12, fig. 7; pl. 13, fig. 8.
Coscinodiscus lineatus Ehrenberg, Hanna, 1932, pl. 8, fig. 3.

Geologic range. Oligocene to Recent.

Ecology. Hustedt (1928, p. 390) states that this species is "Im ozeanischen Plankton der meisten Meere verbreitet und häufig. Findet sich gewöhnlich auch in allen Flussmündungen."

Cupp (1943) cites *C. excentricus* Ehrenberg as being widely distributed, oceanic, often near the coast, but never abundant off California. Hendey (1964, p. 81) reported that this is one of the most common and widespread diatoms in the neritic plankton, with a world-wide distribution.

Remarks. The original description of *C. excentricus* Ehrenberg, appeared in 1839 (p. 146 [1841]). He did not use the present day spelling of the species name *C. excentricus* but rather used the spelling *C. eccentricus*. This was again followed by Ehrenberg in 1841 and 1854; by Kützing (1844); and by W. Smith (1853). The writer has not been able to find any discussion concerning the reason for the change in spelling of the species name.

Figure 14. *Coscinodiscus asteromphalus* Ehrenberg. Hypotype no. 3909 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.1741 mm.

Figure 15. *Coscinodiscus asteromphalus* Ehrenberg. Hypotype no. 3910 (CAS), from locality 27295-102 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Diameter 0.3240 mm.

Figure 16. *Coscinodiscus asteromphalus* Ehrenberg. Hypotype no. 3911 (CAS), from locality 27295-155 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Diameter 0.2312 mm.

Figure 17. *Coscinodiscus asteromphalus* Ehrenberg. Hypotype no. 3912 (CAS), from locality 27295-102 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Diameter 0.2248 mm.

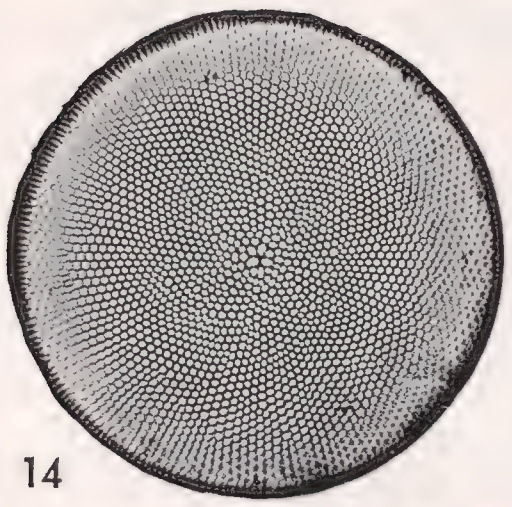
Figure 18. *Coscinodiscus asteromphalus* Ehrenberg. Hypotype no. 3913 (CAS), from locality 27295-155 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Diameter 0.3795 mm.

Figure 19. *Coscinodiscus asteromphalus* var. *omphalantha* (Ehrenberg) Grunow. Hypotype no. 3914 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.1740 mm.

Figure 20. *Coscinodiscus concavus* Gregory. Hypotype no. 3915 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.0650 mm.

Figure 21. *Coscinodiscus confusus* Rattray. Hypotype no. 3916 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.0820 mm.

Figure 22. *Coscinodiscus curvatulus* var. *minor* (Ehrenberg) Grunow. Hypotype no. 3917 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.0420 mm.



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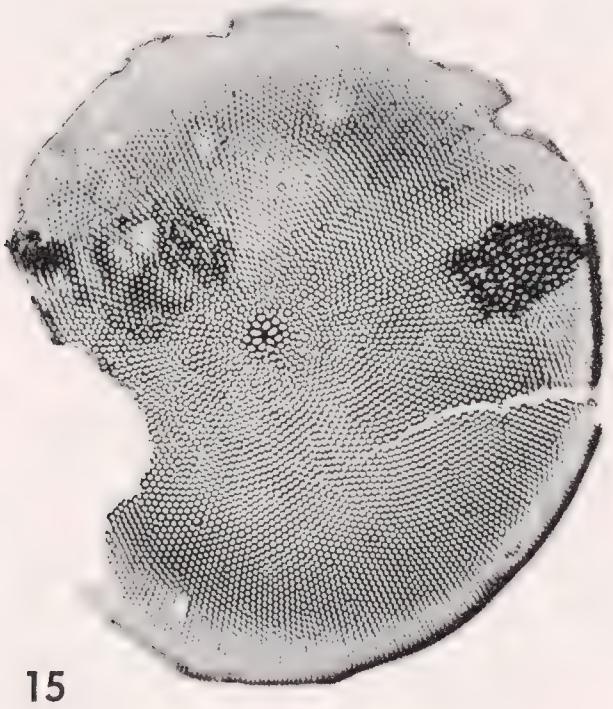

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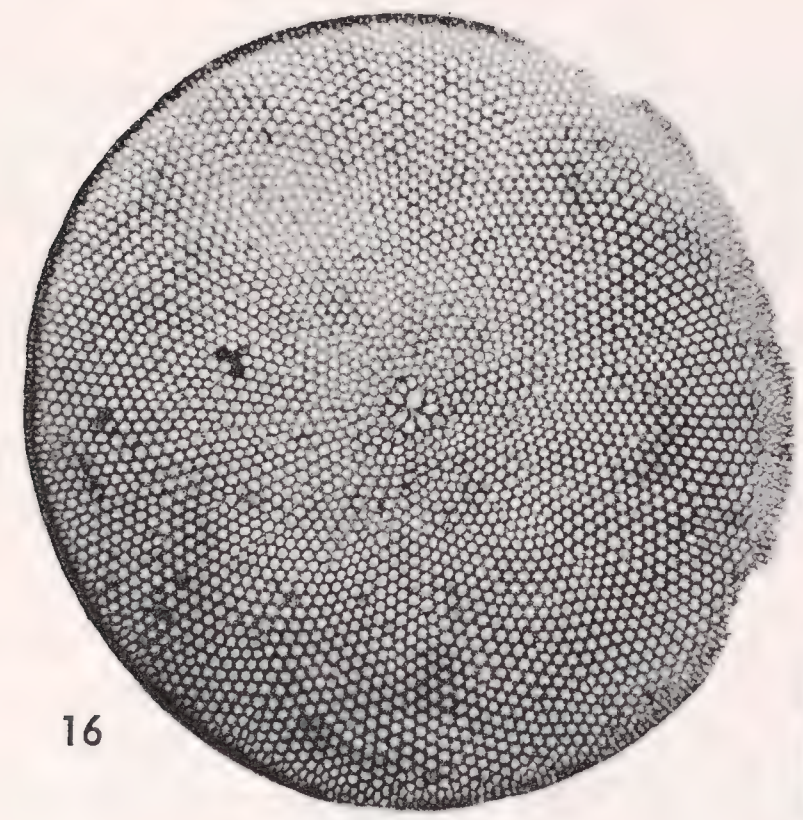

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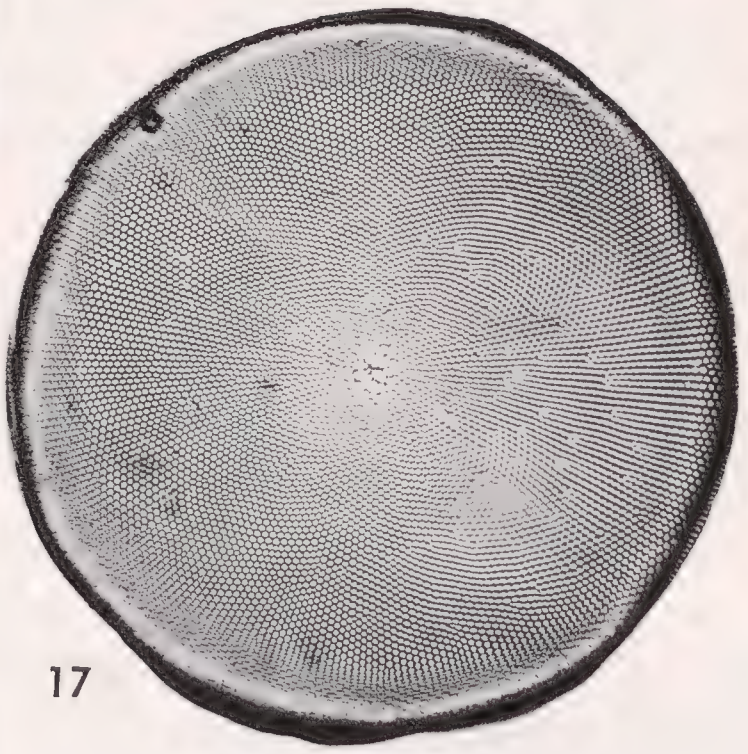

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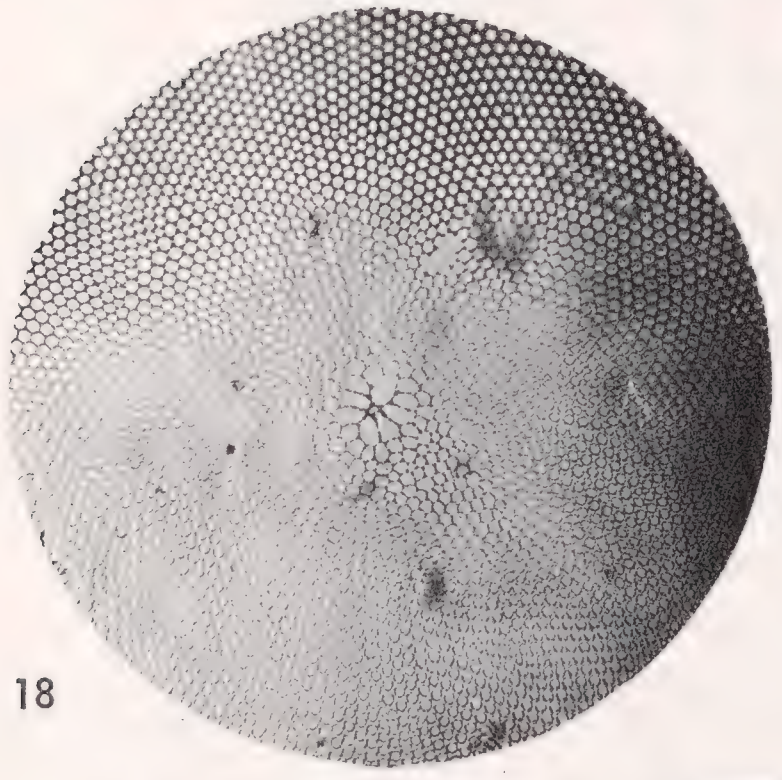

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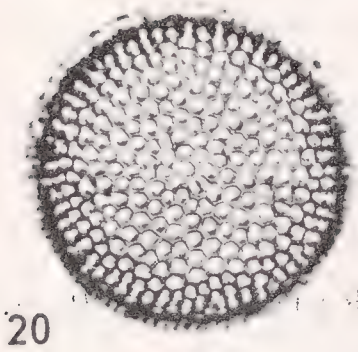

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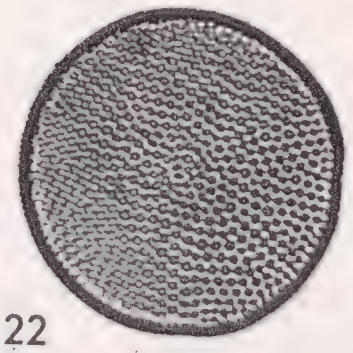

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All the valves of this species do not have the same convexity, some range from flat to moderately convex.

The forms with the same areolation pattern, but without a border of any kind, have been placed with *Planktoniella sol* (Wallich) Schütt.

Hustedt and Lohman and others have put *C. labyrinthus* Roper in synonymy with *C. excentricus* Ehrenberg. The writer, however, feels that this species may be a variety of *C. excentricus* or even a different species entirely based on Roper's original description and illustrations (1858, p. 21). He states, "but the arrangement of the cellules is so different from any yet figured, that it may fairly be entitled to rank as a new species. It has somewhat of the aspect, under low power, of a finely marked specimen of *C. excentricus*, but differs in the absence of a spinous margin, and in the peculiar arrangement of the cellules, which have the appearance of whorls or coils of dots as shown in figure 2b. The surface of the valve is thus divided into large and irregularly shaped hexagonal spaces without any clearly defined margin."

Coscinodiscus gigas var. **diorama** (Schmidt) Grunow.

(Figure 25.)

Coscinodiscus diorama Schmidt, 1878, pl. 64, fig. 2. Cleve-Euler, 1951, p. 64, fig. 93.

Coscinodiscus gigas var. *diorama* (Schmidt) Grunow, 1884, p. 76. Rattray, 1890, p. 94.

Geologic range. Late Miocene to Recent.

Ecology. According to Cleve-Euler (1951, p. 64) "Mar. In südlichen Meeren. *Foss.* u. tertiar mehrere Fragmente in Sudlappl.," and "Eine verwandte Riesenart ist *Cosc. gigas* E. aus warmeren Meeren, der aber gegen das Zentrum ein zusammenhangendes Areolennetz hat."

The species *C. gigas* Ehrenberg is oceanic, widely distributed in tropical and subtropical seas, probably stenohaline, and has its optimum in water of high salinity.

Coscinodiscus kurzii Grunow.

Coscinodiscus kurzii Grunow, *in* Schmidt, 1888, pl. 113, fig. 17. Rattray, 1890, p. 564. Lohman, 1938, pl. 20, fig. 1; pl. 21, fig. 2. Lohman, 1941, p. 71, pl. 13, fig. 5.

Geologic range. Pliocene to Pleistocene.

Coscinodiscus kützingi Schmidt.

Coscinodiscus kützingi Schmidt, 1878, pl. 57, figs. 17, 18. Rattray, 1890, p. 481. Hustedt, 1928, p. 398, fig. 209. Lohman, 1949, p. 161.

GEOLOGIC RANGE. Middle Pliocene to Recent.

ECOLOGY. According to Hendey (1964, p. 81), this is a common neritic species.

REMARKS. This species is characterized by submarginal apiculi, narrow striated border and marginal zone of fine areolae arranged in quincunx. According to Hendey (1964, p. 81), this is a common neritic species.

Coscinodiscus lewisianus Greville.

(Figure 26.)

Coscinodiscus lewisianus GREVILLE, 1866, p. 78,79, pl. 8, figs. 8-10. SCHMIDT, 1886, pl. 66, fig. 121. PANTOCSEK, 1886, p. 73, pl. 25, fig. 232. RATTRAY, 1890, p. 598 (p. 150). REINHOLD, 1937, p. 96, pl. 8, fig. 11. LOHMAN, 1948, p. 161, pl. 6, fig. 7. KOLBE, 1954, p. 30,31, pl. 2, fig. 21.

GEOLOGIC RANGE. Late Miocene.

REMARKS. This species is easily recognized by its characteristic areolation and shape. It has not been found in rocks either older or younger than the Miocene, according to Lohman (1948, p. 161).

Coscinodiscus lineatus Ehrenberg.

Coscinodiscus lineatus EHRENBERG, 1838, p. 129; 1841, p. 371, pl. 1, gr. 3, fig. 20. HANNA AND GRANT, 1926, p. 139, pl. 15, fig. 6; pl. 3, gr. 7, figs. 7, 8. HUSTEDT, 1928, p. 392, fig. 204. HANNA, 1934, p. 355, pl. 48, fig. 9. REINHOLD, 1937, p. 97, pl. 11, fig. 7. LOHMAN, 1941, p. 68, pl. 12, fig. 10. CUPP, 1943, p. 53, figs. 15a, b, c. LONG, FUGE, AND SMITH, 1946, p. 103, pl. 16, fig. 5.

GEOLOGIC RANGE. Late Cretaceous to Recent.

ECOLOGY. A truly neritic diatom, in temperate and subtropical seas according to Hendey (1937, p. 243). "A common and widespread plankton species," as reported by Hendey (1964, p. 76).

This species has been reported to be chiefly oceanic but also frequently neritic in all oceans by Cupp (1943).

Kanaya (1959) suggests that "the high frequency of this species in a diatom thanatocoenosis indicates that its accumulation has taken place under the prevalence of tropical or subtropical waters, rather than of temperate or cold ones."

Coscinodiscus lineatus var. **convexus** (Ehrenberg), new combination.

Coscinodiscus lineatus Ehrenberg, HANNA, 1932, p. 180, pl. 8, figs. 1, 2. SCHMIDT, pl. 114, fig. 13.

GEOLOGIC RANGE. Middle Miocene to middle Pliocene.

REMARKS. This variety can be easily recognized by the linear pattern of areolae, the coarseness of the areolae, and massiveness of the border.

Coscinodiscus lineatus var. **ellipticus** Kolbe.

Coscinodiscus lineatus var. *ellipticus* Kolbe, 1954, p. 32, pl. 11, fig. 15.

Geologic range. Middle Pliocene.

Remarks. This variety has been reported only from one of the cores taken from the Pacific Ocean.

Coscinodiscus lineatus var. **leptopus** Grunow.

(Figure 24.)

Coscinodiscus lineatus var. *leptopus* Pelletan, 1888, p. 181, fig. 433.
Coscinodiscus leptopus Grunow, *in* Van Heurck, 1881, pl. 131, figs. 5, 6. Rattray, 1890, p. 476 (p. 28). Wolle, 1894, pl. 90, fig. 6. De-Toni, 1894, p. 1219. Peragallo, 1904, p. 427, pl. 116, fig. 8. Boyer, 1927, p. 46.
Coscinodiscus lineatus Schmidt, 1886, pl. 59, fig. 26.

Geologic range. Late Miocene to Recent.

Remarks. This variety is distinguished by having the areolae in straight rows, or nearly so, that become granular in a marginal zone, and by one large apiculus near the border.

Coscinodiscus marginatus Ehrenberg.

(Figures 27, 28.)

Coscinodiscus marginatus Ehrenberg, 1841, p. 12 [usually erroneously cited as pp. 142, 421, 241, etc.] [1843] Ehrenberg, 1854, pl. 18, fig. 44; pl. 33, gr. 12, fig. 13, pl. 38B, gr. 22, fig. 8. Schmidt, 1878, pl. 62, figs. 1, 2 ("Monterey"), 3, 4, 9 ("Monterey"), 11, 12. Rattray, 1890, p. 509 (p. 61). Hustedt, 1928, p. 416, fig. 223. Lohman, 1941, p. 71, pl. 14, figs. 1?, 6.
Not *Coscinodiscus marginatus* Ehrenberg of Hanna and Grant, 1926, p. 139, pl. 15, fig. 7.
Coscinodiscus limbatus Ehrenberg, 1840, p. 206 [1841].
Coscinodiscus fimbriatus-limbatus Ehrenberg, 1854, pl. 19, fig. 4.
Coscinodiscus radiatus forma *heterosticta* Grunow, *in* Pantocsek, 1886, p. 70, pl. 20, fig. 184.
Coscinodiscus robustus Schmidt, 1878, pl. 62, fig. 5.
Coscinodiscus subconcavus forma *major* Schmidt, 1878, pl. 62, fig. 7("Monterey").

Geologic range. Late Cretaceous to Recent.

Ecology. This species is reported to live in all warm to temperate seas by Lohman (1941) and also in boreal to cold waters by Jouse (1957). It is interesting to note that Kolbe did not find this species in the equatorial deep-sea cores of the Atlantic (1956) or the Indian Oceans (1957), but did record it occurring frequently in the cores from the Equatorial Pacific (1954).

Common in all temperate seas, probably a bottom form, and meroplanktonic, according to Hendey (1937, p. 248). Also as stated by Hendey (1964, p. 78), "An oceanic species frequent in North Atlantic water, North Sea."

REMARKS. This species is characterized by broad, massive margins (borders), somewhat obscure radial areolae slightly diminishing toward the border, and by the great convexity of the valve.

Coscinodiscus marginatus has been frequently confused with *Endictya robustus* (Greville), but the latter species has valves that are cup-shaped, not convex disks. The marginal bands turn vertically downward from the disk and are ornamented, like the face of the valve, with a coarse network.

Coscinodiscus monicae Grunow.

(Figure 29.)

Coscinodiscus janischii var. ?*monicae* GRUNOW, 1884, p. 76.

Coscinodiscus monicae Grunow, RATTRAY, 1890, p. 563 (p. 115. DE-TONI, 1894, p. 1278. SCHMIDT, 1877, pl. 63, fig. 10 [unnamed, but named in Fricke's Index, 1902]. HANNA, 1932, p. 182, pl. 9, fig. 2. LOHMAN, 1948, p. 162, pl. 7, fig. 6.

GEOLOGIC RANGE. Middle Miocene to late Miocene.

REMARKS. This species has no secondary markings, the areolae seem to vary considerably, and the central large areolae may or may not be in contact with one another.

Coscinodiscus nitidus Gregory

(Figures 30, 31.)

Coscinodiscus nitidus GREGORY, 1857, p. 27, pl. 1, fig. 45. RATTRAY, 1890, p. 478 (p. 30). HANNA AND GRANT, 1926, p. 140, pl. 15, fig. 9. HUSTEDT, 1928, p. 414, fig. 221b.

GEOLOGIC RANGE. Late Cretaceous to Recent.

ECOLOGY. The species is meroplanktonic, probably a bottom form, according to Hendey (1937, p. 242).

REMARKS. Although Hustedt (1928, p. 413) placed *Coscinodiscus nitidulus* Grunow in synonymy with the above species, I believe that there is ample justification for making a distinction between the two species.

Coscinodiscus obscurus Schmidt.

(Figure 32.)

Coscinodiscus obscurus SCHMIDT, 1878, p. 61, fig. 16. RATTRAY, 1890, p. 513. HUSTEDT, 1928, p. 418, fig. 224.

GEOLOGIC RANGE. Late Cretaceous to Recent.

ECOLOGY. This species is "Pelagisch im Nordatlantischen Ozean!" according to Hustedt (1928, p. 420). Hendey (1957, p. 37), however, states that it "is probably a member of the oceanic plankton."

Coscinodiscus oculus-iridis var. **borealis** (Bailey) Cleve.

(Figure 33.)

Coscinodiscus borealis Bailey, 1856, p. 3. Schmidt, 1878, p. 63, fig. 11. Rattray, 1890, p. 558.

Coscinodiscus oculus-iridis var. *borealis* (Bailey) Cleve, 1883, p. 488. Hustedt, 1928, p. 456, fig. 253.

Geologic range. Late Miocene to Recent.

Ecology. According to Lohman (1941, p. 73) this species is definitely a cold-water form.

Remarks. This variety is characterized by large areolae and by a raised area which is present about 1/5 of the radius from the margin.

Coscinodiscus oculus-iridis Ehrenberg.

(Figures 34, 35.)

Coscinodiscus oculus-iridis Ehrenberg, 1839, p. 147 [1841]. Ehrenberg, 1854, pl. 18, fig. 42; pl. 19, fig. 2. Schmidt, 1878, pl. 63, figs. 6, 7, 9; 1888, pl. 113, figs. 1, 3, 5, 20. Rattray, 1890, p. 559. Hanna and Grant, 1926, p. 141, pl. 15, fig. 11. Hustedt, 1928, p. 454, fig. 252.

Geologic range. Late Eocene to Recent.

Ecology. Hendey (1937, p. 249) states that this is "probably an oceanic species, but in the material examined it was always found as a mero-

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Figure 23. *Coscinodiscus antiquus* Grunow. Hypotype no. 3918 (CAS), from locality 27295-7 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Diameter 0.0348 mm.

Figure 24. *Coscinodiscus lineatus* var. *leptopus* Grunow. Hypotype no. 3919 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.1840 mm.

Figure 25. *Coscinodiscus gigas* var. *diorama* (Schmidt) Grunow. Hypotype no. 3920 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.0220 mm.

Figure 26. *Coscinodiscus lewisianus* Greville. Hypotype no. 3921 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0450 mm., breadth 0.0250 mm.

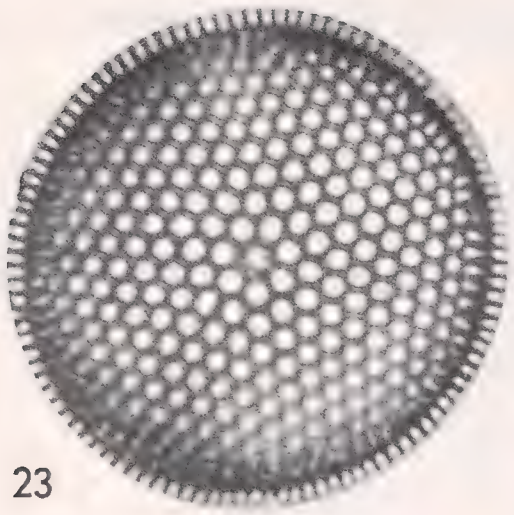
Figure 27. *Coscinodiscus marginatus* Ehrenberg. Hypotype no. 3922 (CAS), from locality 27295-155 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Diameter 0.1708 mm.

Figure 28. *Coscinodiscus marginatus* Ehrenberg. Hypotype no. 3923 (CAS), from locality 27295-155 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Diameter 0.1780 mm.

Figure 29. *Coscinodiscus monicae* Grunow. Hypotype no. 3924 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.2040 mm.

Figure 30. *Coscinodiscus nitidus* Gregory. Hypotype no. 3925 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.0510 mm.

Figure 31. *Coscinodiscus nitidus* Gregory. Hypotype no. 3926 (CAS), from locality 866 (CAS) Monterey, California. Diameter 0.1085 mm.



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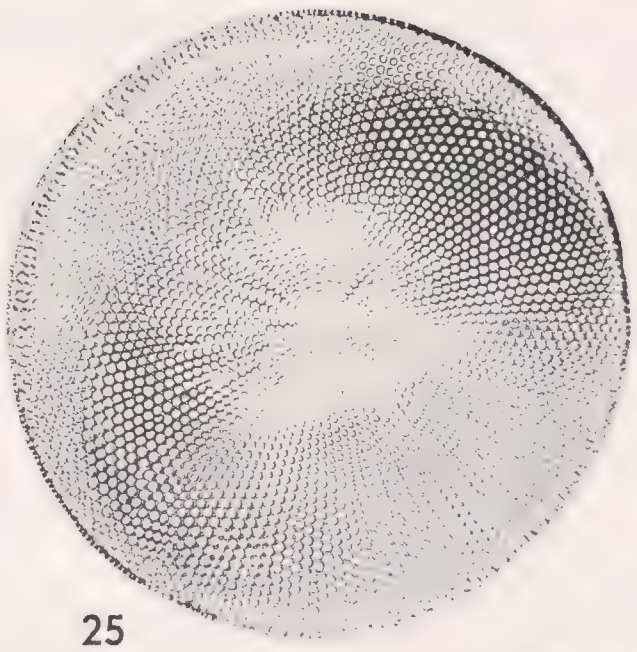

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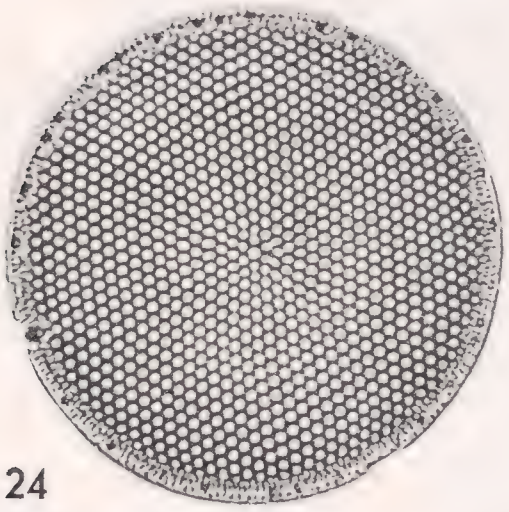

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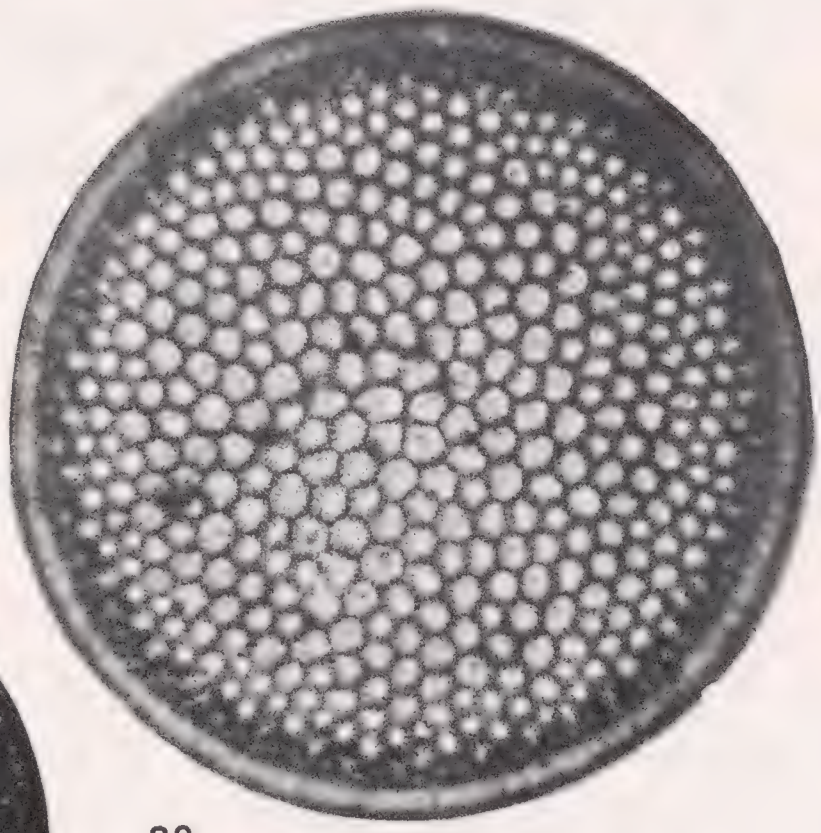

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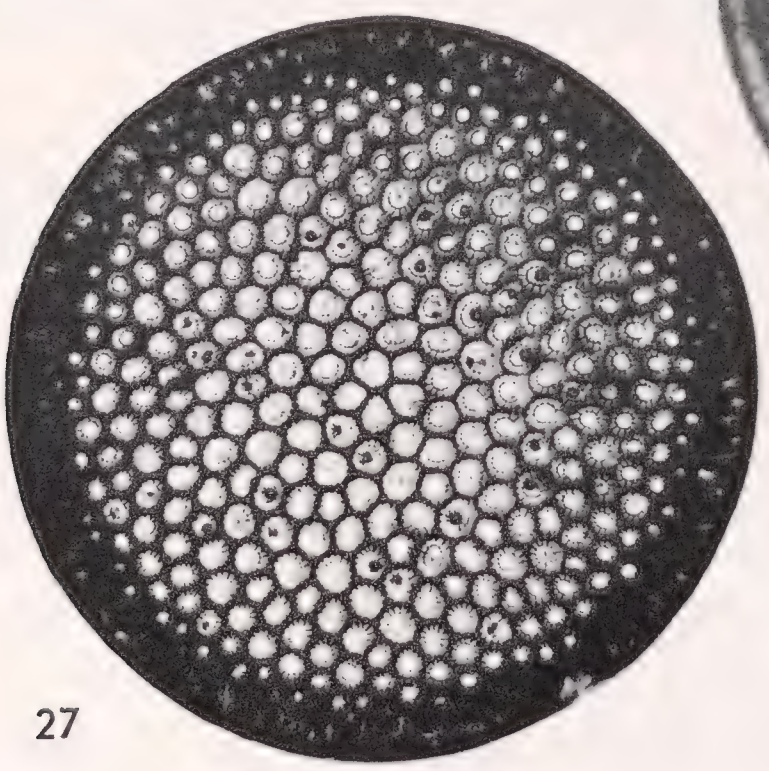

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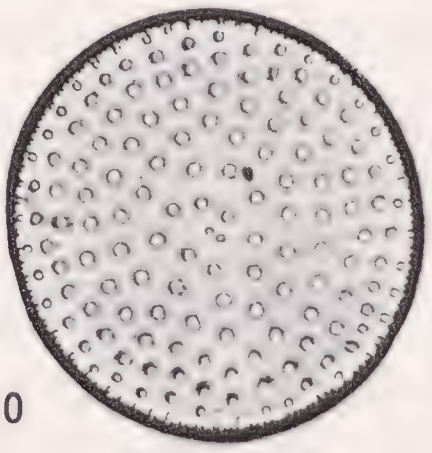

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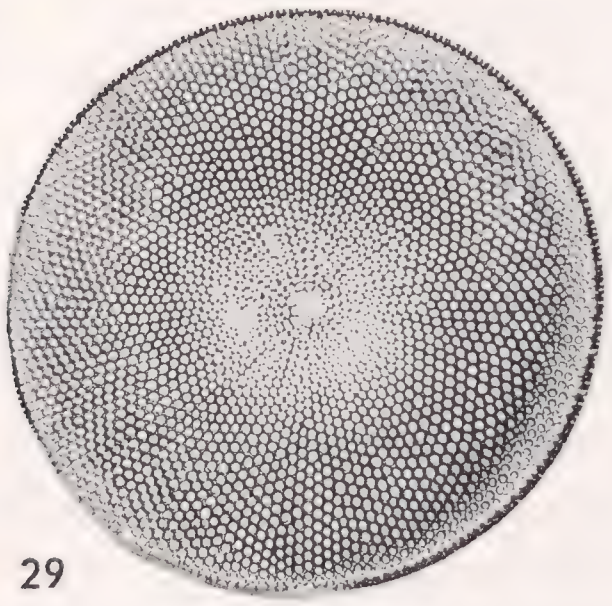

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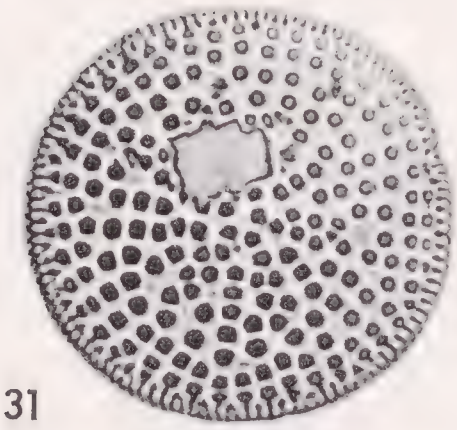

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planktonic form." Also, according to Hendey (1964, p. 78), "it is an oceanic pelagic species found all over the world."

Remarks. Distinguished from *Coscinodiscus pacificus* Rattray in having a more distinct rosette, and marginal apiculi. The latter can be distinguished by the increase in size of the areolae toward the central portion of the valve surface.

Coscinodiscus pacificus Rattray.

(Figures 36, 37.)

Coscinodiscus oculus iridis var. *?pacifica* Grunow, 1884, p. 77.
Coscinodiscus pacificus Rattray, 1890, p. 563 [name for pl. 60, fig. 13, of Schmidt's Atlas, 1877]. Hanna and Grant, 1926, p. 142, pl. 16, fig. 1. Hanna, 1932 p. 184, pl. 10, fig. 1.

Geologic range. Middle Miocene to Recent.

Coscinodiscus perforatus Ehrenberg.

(Figure 38.)

Coscinodiscus perforatus Ehrenberg, 1844, p. 78; 1854, pl. 18, fig. 46. Schmidt, 1878, pl. 64, figs. 12-14. Rattray, 1890, p. 571 (p. 123). Hustedt, 1928, p. 445-447, fig. 245. Lohman, 1948, p. 163.

Geologic range. Middle Miocene to Recent.

Ecology. According to Hustedt (1928, p. 448), it occurs "In allen europäischen Meeren im Plankton verbreitet, doch meist vereinzelt." Hustedt (1955, p. 6) also stated that this species is "Rather frequent, especially on the mud from piles in the harbor." According to Hendey (1964, p. 78) this species is frequently present in the plankton of the North Sea.

Remarks. The areolae are smaller near the central space and near the margin.

Coscinodiscus perforatus var. **cellulosa** Grunow.

Coscinodiscus perforatus var. *cellulosa* Grunow, 1884, p. 75. Schmidt, 1888, pl. 114, fig. 5. Rattray, 1890, p. 572. Hustedt, 1928, p. 447, fig. 246. Lohman, 1948. pp. 163, 164, pl. 8, fig. 3.

Geologic range. Late Miocene to Recent.

Ecology. It is usually found in the same environment with the typical species.

Remarks. This variety is characterized by small punctae at the origin of the shorter radial rows of the areolae. The areolae are constant from 9/10 to 1/10 of the radius, becoming smaller at the border.

It is usually found in the same environment with the typical species.

Coscinodiscus radiatus Ehrenberg.

(Figure 39.)

Coscinodiscus radiatus Ehrenberg, 1839, p. 148, pl. 3, figs. 1 a-c [1841]. Schmidt, 1886, pl. 60, figs. 5, 6, 9, 10; pl. 61, fig. 13 (unnamed); pl. 65, fig. 8 (unnamed). Rattray, 1890, p. 514 (p. 66). De-Toni, 1894, p. 1244. Hanna and Grant, 1926, p. 142, pl. 15, fig. 12. Hanna, 1927, p. 112, pl. 18, fig. 2. Hustedt, 1928, p. 420, fig. 225. Lohman, 1941, p. 73, pl. 15, figs. 7, 8. Cupp, 1943, p. 56, fig. 20; pl. 1, fig. 4.

Geologic range. Late Cretaceous to Recent.

Ecology. Lohman (1941, p. 57) states that this species is confined to "warm to temperate seas," and it is "marine, neritic-oceanic, warm". Recorded by Cupp (1943, p. 56) as "Oceanic and neritic. Ubiquitous. Never in large numbers in California, but not uncommon."

Capable of living and reproducing in coastal waters, according to Lebour (1930, p. 39).

Remarks. Valves fairly flat. Coarse areolae, 2-4 in 0.01 mm., decreasing very slightly in size to the border area where they increase in number to 6-7 in 0.01 mm. No interstitial meshes. No central rosette or central area developed. Areolation irregular. Margin narrow with radial striae.

Coscinodiscus robustus (Greville).

(Figure 40, 41.)

Coscinodiscus robustus Greville, 1886, p. 3, pl. 1, fig. 8. Truan and Witt, 1888, p. 14, pl. 3, fig. 5. Rattray, 1890, p. 511 (p. 53). Boyer, 1927, p. 54.

Not *Coscinodiscus robustus* Greville *in* Schmidt, 1877, pl. 62, figs. 16, 17. Reinhold, 1937, p. 101, pl. 9, fig. 5.

Coscinodiscus subvelatus Grunow, *in* Schmidt, 1881, pl. 65, fig. 9.

Not *Endictya robusta* (Greville) Hanna and Grant *in* Lohman, 1941, p. 66, pl. 12, fig. 4.

Not *Endictya robusta* (Greville) Hanna and Grant, 1926, p. 144, pl.16, figs. 2, 3.

Geologic range. Late Miocene to Recent.

Remarks. Central space absent. Areolation pattern variable. Areolae coarse. Three areolae in 0.01 mm. in the central region continuing nearly equal in size to the margin, where they decrease slightly to four areolae in 0.01 mm. However, the cellules appear rounded and become increasingly smaller in appearance toward the margin. Interstitial meshes absent or very rare. Valve surface is convex over the central 4/5 portion of the valve, then the marginal area rises rapidly and depresses rapidly to the finely striated border. (This marginal area is like a small, sharp but rounded hill.)

I have examined many specimens of the referred species and have found them to agree with Greville's original figure. However, to see the fine striae that appears so clearly in his type figure, one must focus very carefully on the border area of forms belonging to this species.

Coscinodiscus robustus var. **herculus** J. Brun.

(Figure 42.)

Coscinodiscus robustus var. *herculus* J. Brun. "Coscinodiscus Herculus *J. Brun* (SUBVELATUS *Grun.* VAR.)", Brun, 1891, p. 22, pl. 21, fig. 5.

Geologic range. Pliocene.

Remarks. Brun states, "Plus grand et plus robuste que le type 65.9 de l'atlas. Il differe aussi sensiblement de la forme 62, 16, 17 dessinée comme var. du *robustus*. Sendai. Yedo. Santa Maria. Rare."

Valves convex, coarse areolae, 2 to 2½ in 0.01 mm., over entire valve surface. Border area about 0.0020 mm. in photomicrograph.

Coscinodiscus robustus var. **incretus** (Schmidt).

(Figure 43.)

Coscinodiscus robustus Greville, Schmidt, 1886, pl. 62, figs. 16, 17. Tempère and agallo, 1890, p. 230.

Coscinodiscus incretus Schmidt, 1888, pl. 139, figs. 1, 1a.

Geologic range. Late Miocene.

Remarks. This variety differs from the typical species in possessing coarse areolae and large chamber openings in the central region, occupying about 2/5 to 1/2 the diameter of the valve. The chamber openings diminish rapidly from the central region to the border zone about 1/5 to 1/4 the diameter, from 2 to 4 in 0.01 mm., and remain about the same size to the wide, fine striated border.

The marginal area including the elevated rim appears as a dark area in photomicrographs, and is about 0.02 mm. wide. The rim, of course, is best seen in a girdle view.

According to Mann (1925, p. 67, 68) "a recent examination of many specimens of *Coscinodiscus robustus* Greville, collected in Monterey Bay, California, the original locality of Greville's type specimen, unmistakably shows that it is not a *Coscinodiscus* but an *Endictya.*" If Mann considered this new species to be Greville's type specimen, then his statement would be true. But this new species has such a broad characteristic rim that I feel confident such an able diatomist as Greville would have seen the elevated rim and could not have seen the delicate, finely striated border that appears in his original type figure. I have placed specimens such as Greville describes with some variation in areolation pattern under *Coscinodiscus robustus* Greville.

Genus **Craspedodiscus** Ehrenberg, 1845

Craspedodiscus rhombicus Grunow.

(Figures 44, 45.)

Craspedodiscus rhombicus GRUNOW, *in* Schmidt, 1878, pl. 66, fig. 13.

GEOLOGIC RANGE. Late Miocene.

Genus **Cyclotella** Kützing, 1834

Cyclotella kelloggi Hanna.

(Figure 46.)

Cyclotella kelloggi HANNA, 1932, p. 185, pl. 10, figs. 2-4.

GEOLOGIC RANGE. Middle Miocene to late Miocene.

Genus **Actinocyclus** Ehrenberg, 1838

Actinocyclus cubitus Hanna and Grant.

(Figures 47, 48.)

Actinocyclus cubitus HANNA AND GRANT, 1926, p. 118, pl. 11, fig. 3.

GEOLOGIC RANGE. Late Miocene.

REMARKS. This species is characterized by rows of areolae that are parallel to those radii which bisect the sectors of the valve.

Actinocyclus octonarius Ehrenberg.

(Figure 49.)

Actinocylus octonarius EHRENBERG, 1838, p. 172. HENDEY, 1937, p. 262. LOHMAN, 1941, p. 77, pl. 16, fig. 4; 1948, p. 167, pl. 8, fig. 8.

Actinocyclus ehrenbergii RALFS *in* Pritchard, 1861, p. 834. RATTRAY, 1890, pp. 171-182. HUSTEDT, Kieselalgen, 1929, pp. 525-528, fig. 299. LOHMAN, 1938, p. 83, pl. 22, fig. 1.

GEOLOGIC RANGE. Middle Miocene to Recent.

ECOLOGY. "A neritic species, having a cosmopolitan distribution; particularly numerous in temperate seas," according to Hendey (1937, p. 262). Brackish-water and tychopelagic occurrences from Scandinavian localities were reported by Cleve-Euler (1952, p. 81). Hendey (1964, p. 83) stated that this species is found "in neritic plankton."

REMARKS. Valve circular, markings granular, areolae are 7-10 in 0.01 mm. radiating in flexuose lines from center, double lines of radiation appear to divide valve into radial compartments due to the interfasciculate rows

I have examined the plesiotypes of Hanna and Grant's *Endictya robusta* Greville and I have found them to represent two different species of *Coscinodiscus*.

Lohman (1941), following Hanna and Grant, places a form (pl. 12, fig.

4), which he compares with Hanna and Grant's (pl. 16, fig. 2) under the genus *Endictya*. I cannot tell whether or not this belongs to *Endictya* without seeing it in girdle view, but I can state that the dark border, so characteristic in photomicrographs of this genus, is not present.

The main problem in the identification of this genus has been the lack of girdle views along with the valve view of the species concerned. When the girdle view is present (see Hustedt, 1928, p. 298, fig. 139), there is no doubt as to whether the species belongs to *Coscinodiscus* or to *Endictya*. having hyaline spaces on each side at the origin of secondary rows. Pseudoocellus distinct, submarginal. Under low magnification, most valves produce prismatic colors. Valves range from 0.0580 mm. to 0.0920 mm. in diameter.

The valid name *Actinocyclus octonarius* Ehrenberg is used here in place of the well known but invalid name *Actinocyclus ehrenbergii* Ralfs, following Hendey (1937, pp. 262, 263), and Lohman (1941, p. 77; 1948, p. 167).

In regard to the history of this species, the author would like to add a few comments to help clear up its already complex history. Ehrenberg (1854, Tafel 18, fig. 10) illustrated a figure of *Actinocyclus octonarius* = *A. ehrenbergii* and *Actinoptychus senarius* (Tafel 18, fig. 21). He also illustrated a figure of *Actinoptychus octonarius* (Tafel 18, fig. 22), an *Actinoptychus* with eight compartments.

Actinocyclus octonarius var. **tenellus** (Brébisson) Hendey.

Eupodiscus tenellus Brébisson, 1854, p. 257, pl. 1, fig. 9.
Actinocyclus ehrenbergii var. *tenella* (Brébisson) Hustedt, 1929, p. 530, fig. 302.
Kanaya, 1959, p. 95, pl. 7, figs. 2, 3.

Geologic range. Lower Pliocene.

Figure 32. *Coscinodiscus obscurus* Schmidt. Hypotype no. 3927 (CAS), from locality 27295-7 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Diameter 0.1300 mm.

Figure 33. *Coscinodiscus oculus-iridis* var. *borealis* (Bailey). Hypotype no. 3928 (CAS), from locality 27295-155 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Diameter 0.2228 mm.

Figure 34. *Coscinodiscus oculus-iridis* Ehrenberg. Hypotype no. 3929 (CAS), from locality 27295-155 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Diameter 0.2230 mm.

Figure 35. *Coscinodiscus oculus-iridis* Ehrenberg. Hypotype no. 3930 (CAS), from locality 27295-155 (CAS), Harris grade, Purisima Hills, Santa Barbara County, Diameter 0.2440 mm.

Figure 36. *Coscinodiscus pacificus* Rattray. Hypotype no. 3931 (CAS), from locality 27295-25 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Diameter 0.1400 mm.

Figure 37. *Coscinodiscus pacificus* Rattray. Hypotype no. 3931a (CAS), from locality 27295-25 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Diameter 0.1146 mm.

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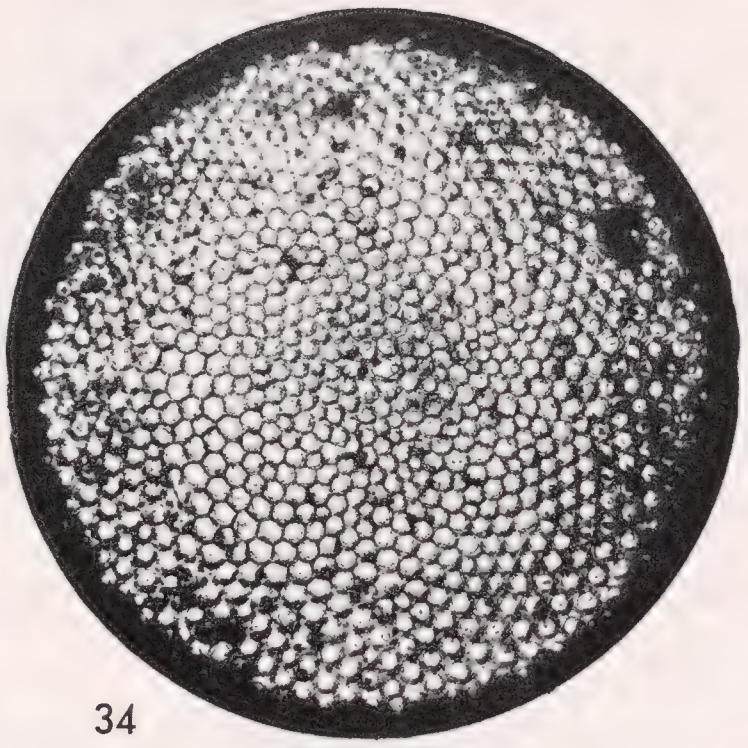

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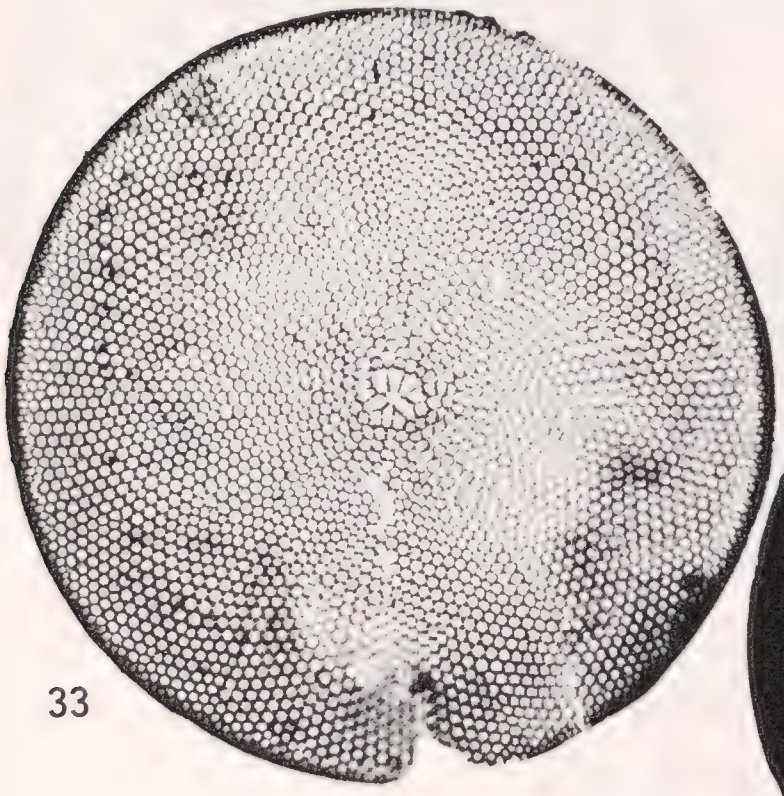

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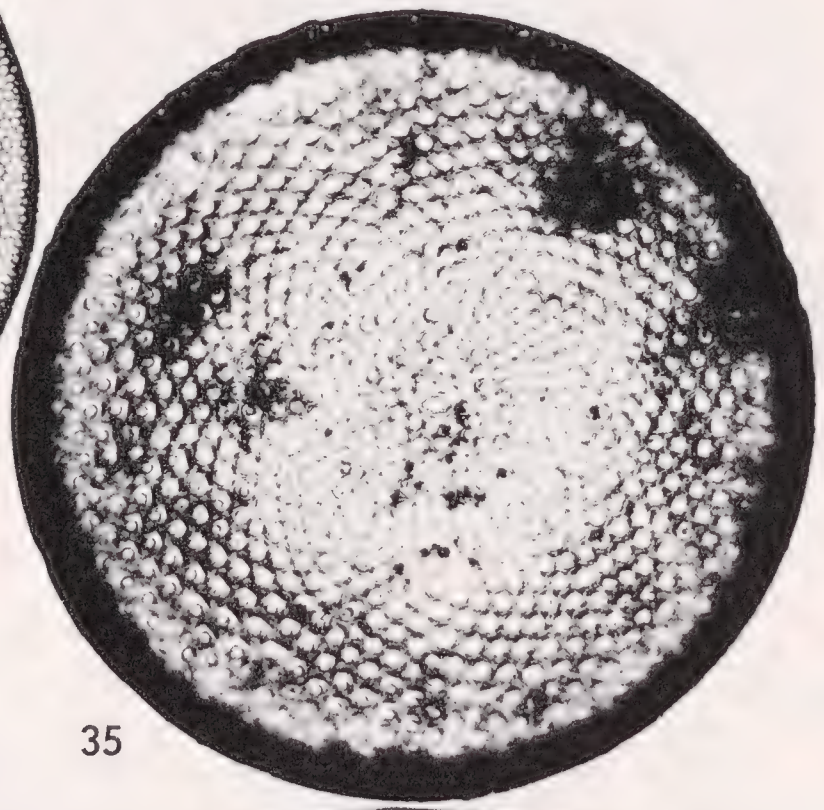

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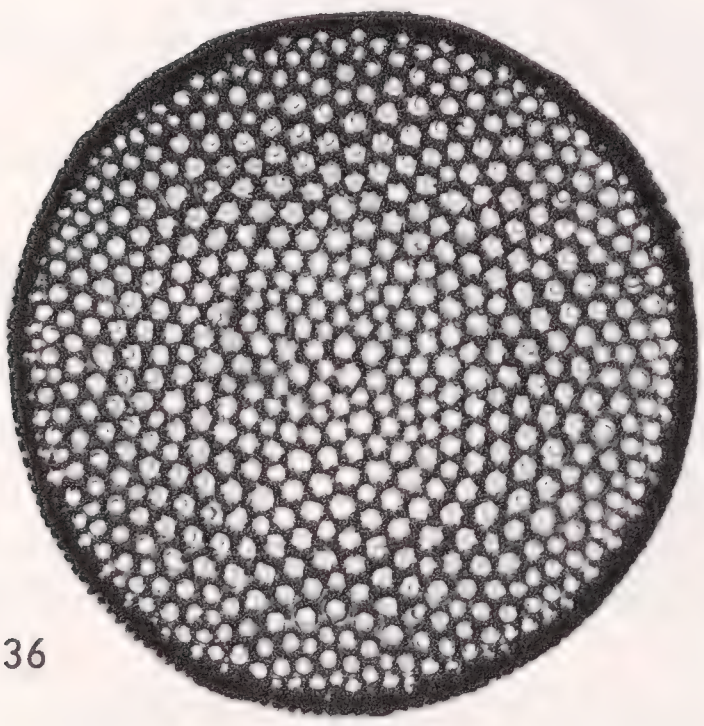

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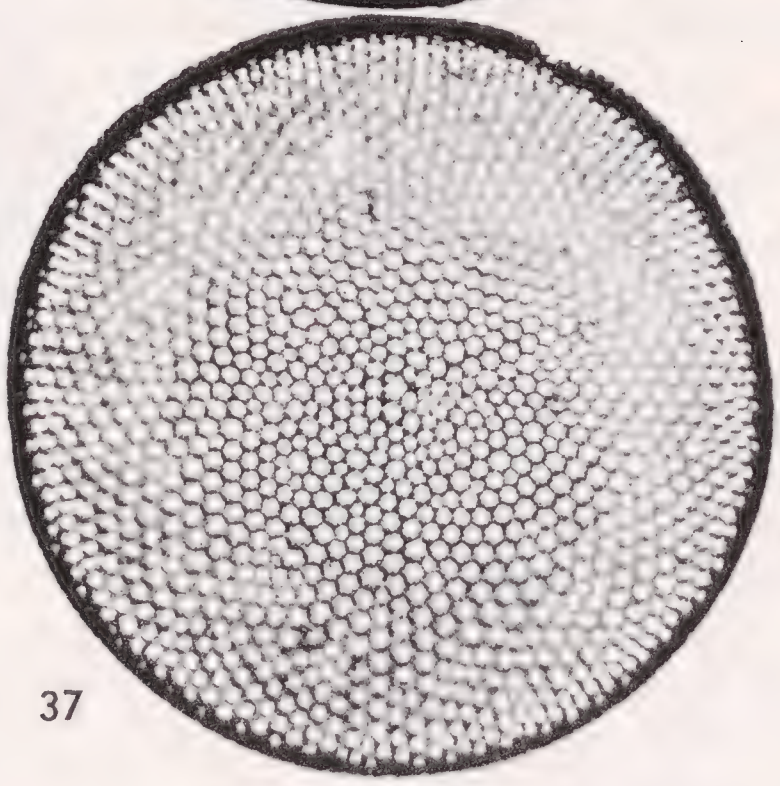

37

Ecology. According to Hendey (1964, p. 84) this variety is found in the "neritic plankton on all British coasts."

Remarks. Valve discoid, surface flat from center to submarginal area, then sloping downwards to the border. Valve divided into relatively few (five to eight) sectors (compartments), by radial rays, composed of single dots (areolae). Interfascicular rows of areolae extend parallel to the middle row of each sector. Submarginal zone well developed, with very small areolae. Pseudo-ocellus (pseudo-nodule) submarginal and distinct. Valves range from 0.0490 to 0.0580 mm. in diameter.

Actinocyclus pyrotechnicus Derby.

(Figure 50.)

Actinocyclus pyrotechnicus Derby, *in* Rattray, 1890, p. 144, pl. 11. fig. 15. Hanna and Grant, 1926, p. 119, pl. 11, fig. 4.

Geologic range. Late Miocene.

Family Hemidiscaceae Hendey, 1937 [12]

Subfamily Hemidiscoideae Hendey, 1937 [12]

Genus **Hemidiscus** Wallich, 1860

Hemidiscus cuneiformis Wallich.

(Figure 51.)

Hemidiscus cuneiformis Wallich, 1860, p. 42, pl. 2, figs. 3, 4. Hustedt, 1930, p. 904, figs. 542 b-c. Cupp, 1943, p. 170, fig. 121.

Geologic range. Late Miocene to Recent.

Ecology. This is an oceanic species widely distributed throughout tropical waters, according to Hendey (1937, p. 264).

Figure 38. *Coscinodiscus perforatus* Ehrenberg. Hypotype no. 3932 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.0830 mm.

Figure 39. *Coscinodiscus radiatus* Ehrenberg. Hypotype no. 3933 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.1080 mm.

Figure 40. *Coscinodiscus robustus* (Greville). Hypotype no. 3934 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.1300 mm.

Figure 41. *Coscinodiscus robustus* (Greville). Hypotype no. 3935 (CAS), from locality 27295-155 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Diameter 0.1506 mm.

Figure 42. *Coscinodiscus robustus* var. *herculus* J. Brun. Hypotype no. 3936 (CAS), from locality 27295-155 (CAS), Harris grade, Purisima Hills, Santa Barbara, California. Diameter 0.1332 mm.

Figure 43. *Coscinodiscus robustus* var. *incretus* (Schmidt). Hypotype no. 3937 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.1190 mm.

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12 Hendey, 1937, p. 202.

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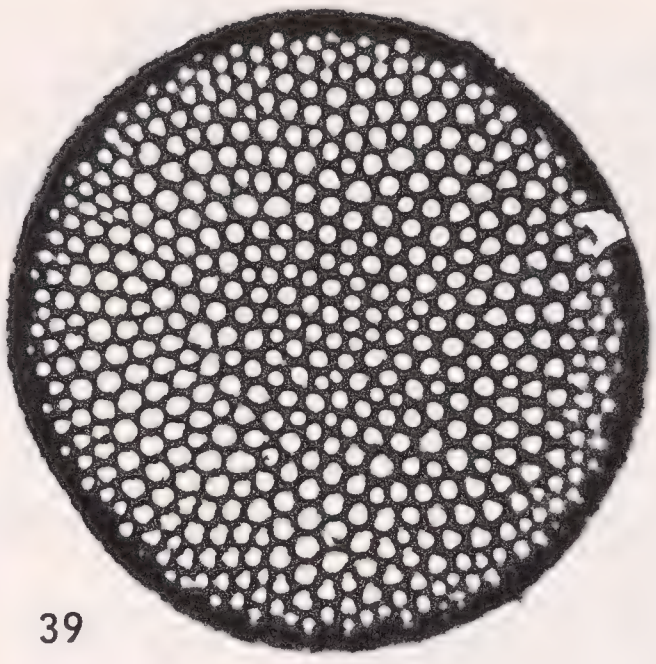

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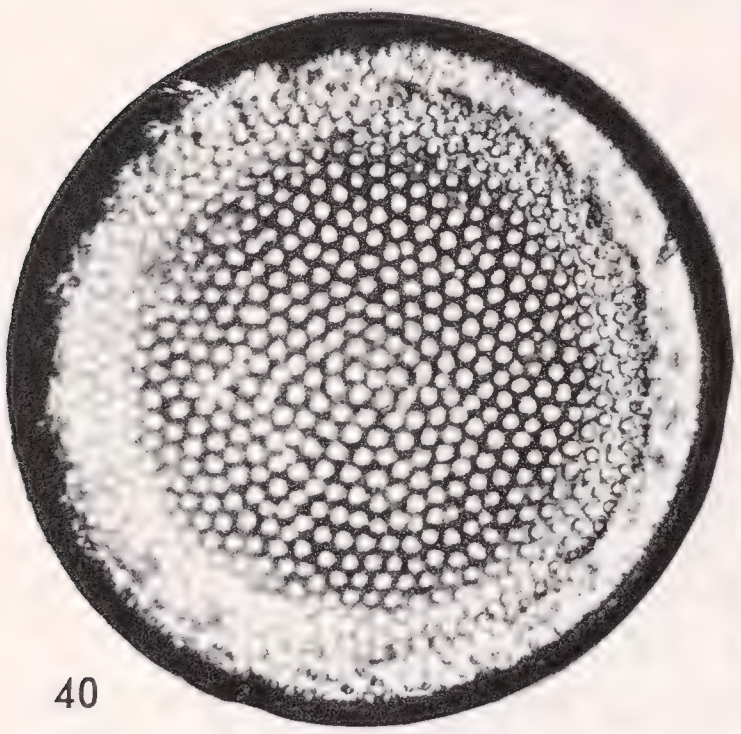

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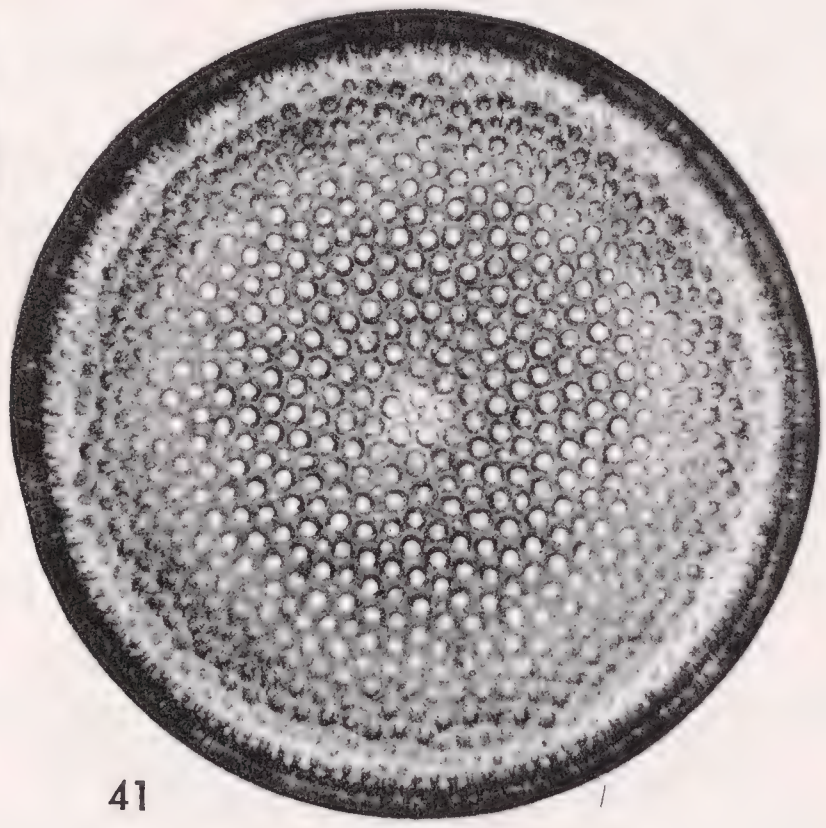

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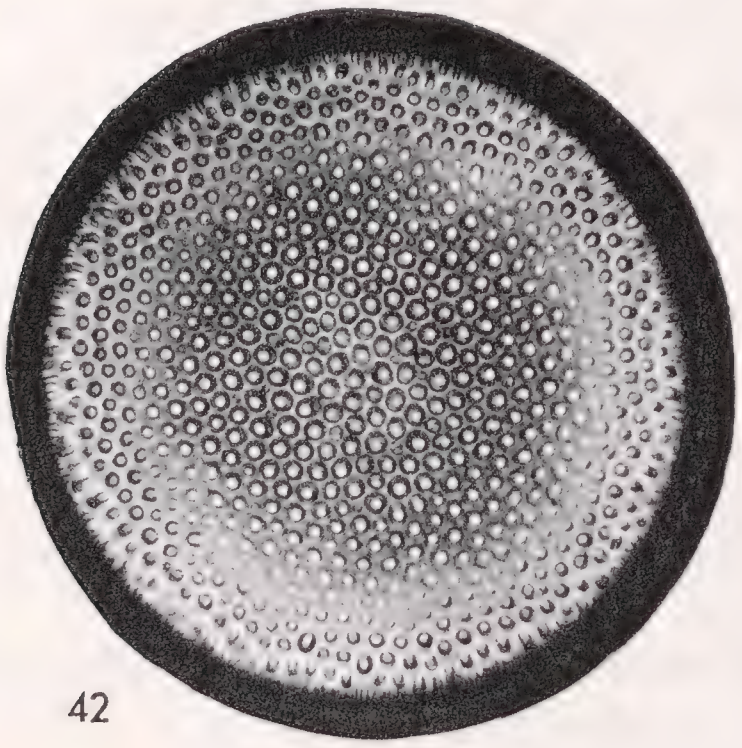

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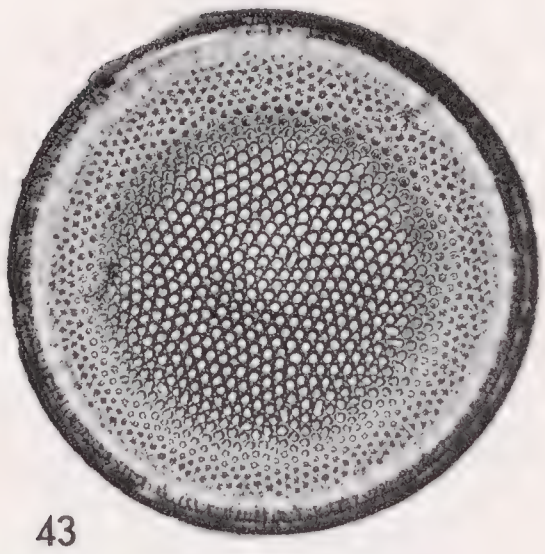

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Family Actinodiscaceae Schütt, 1896 [12a, 12b]

Subfamily Stictodiscoideae Schütt, 1896 [12c, 12d]

Genus **Stictodiscus** Greville, 1861

Stictodiscus buryanus Grunow.

(Figure 52.)

Stictodiscus buryanus Grunow, 1861, p. 40, pl. 4, fig. 1. Hustedt, *in* Schmidt, 1940, pl. 441, fig. 9; pl. 442, fig. 1.

Geologic range. Late Miocene to Pliocene.

Stictodiscus californicus Greville.

(Figures 54, 55.)

Stictodiscus californicus Greville, 1861, p. 79, pl. 10, fig. 1. Hustedt, *in* Schmidt, 1940, pl. 44, figs. 1-9.

Stictodiscus californicus var. *ecostata* Grunow. Schmidt, 1882, pl. 74, fig. 7 (only).

Geologic range. Late Miocene to Pliocene.

Genus **Arachnoidiscus** Bailey from Ehrenberg, 1849

Figure 44. *Craspedodiscus rhombicus* Grunow. Hypotype no. 3938 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0340 mm., breadth 0.0210 mm.

Figure 45. *Craspedodiscus rhombicus* Grunow. Hypotype no. 3939 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0300 mm.

Figure 46. *Cyclotella kelloggi* Hanna. Hypotype no. 3940 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.0370 mm.

Figure 47. *Actinocyclus cubitus* Hanna and Grant. Hypotype no. 3941 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.0310 mm.

Figure 48. *Actinocyclus cubitus* Hanna and Grant. Hypotype no. 3942 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.0470 mm.

Figure 49. *Actinocyclus octonarius* Ehrenberg. Hypotype no. 3943 (CAS), from locality 27295-25 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Diameter 0.0982 mm.

Figure 50. *Actinocyclus pyrotechnicus* Derby. Hypotype no. 3944 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.0950 mm.

Figure 51. *Hemidiscus cuneiformis* Wallich. Hypotype no. 3945 (CAS), from locality 27295-94 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Diameter 0.1220 mm.

Figure 52. *Stictodiscus buryanus* Grunow. Hypotype no. 3122 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.1090 mm.

12a Schütt, 1896, p. 55, as tribe Actinodisceae.

12b Hendey, 1937, p. 202, new status and change in spelling.

12c Schütt, 1896, p. 55, as subtribe Stictodiscinae.

12d Hustedt, 1930, p. 56, new status and change in spelling.

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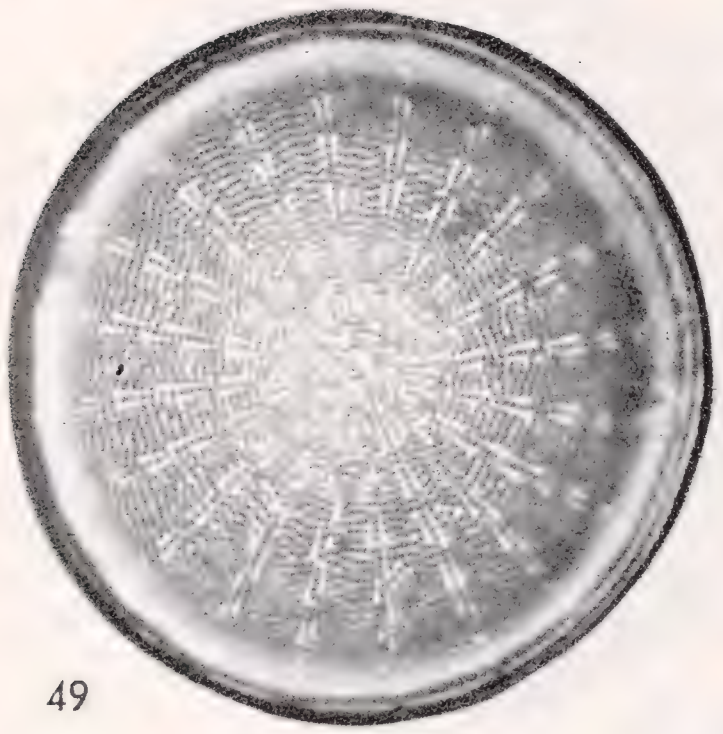

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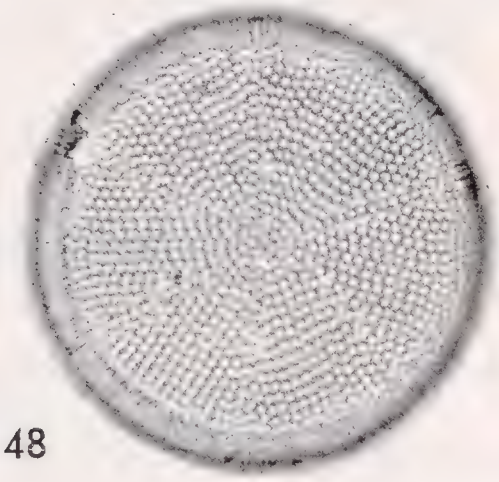

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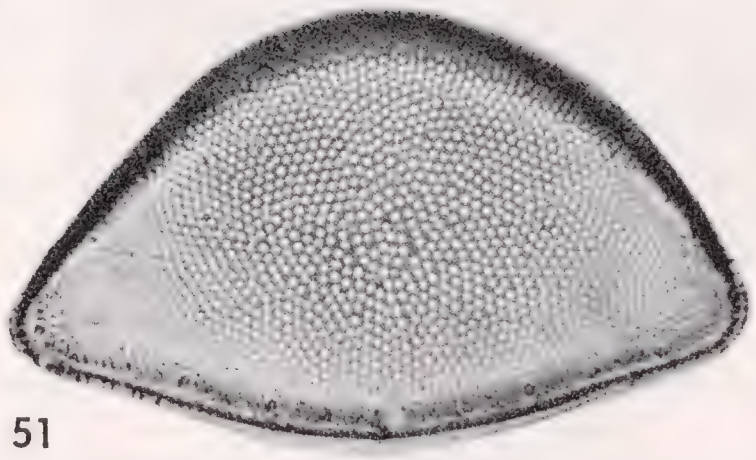

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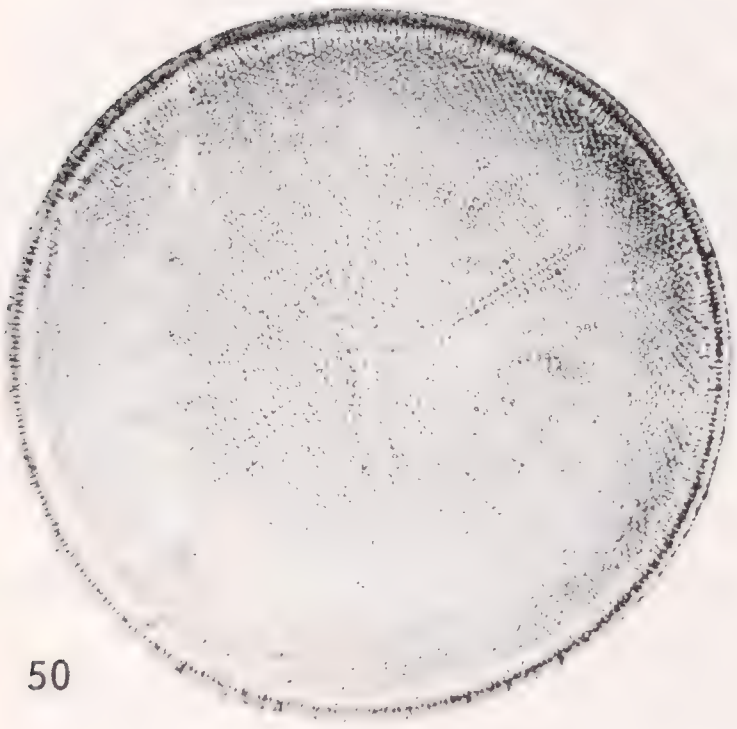

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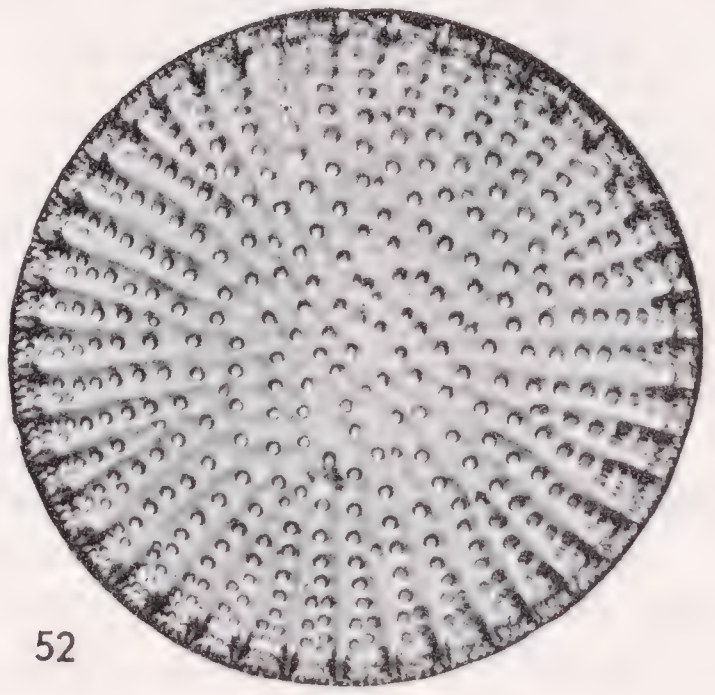

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Arachnoidiscus decorus Brown

(Figure 53.)

Arachnoidiscus decorus Brown, 1933, pp. 71-73, pl. 6, fig. 3.

Geologic range. Late Miocene.

Arachnoidiscus ehrenbergii Bailey.

(Figures 56-60.)

Arachnoidiscus ehrenbergii Bailey, *in* Ehrenberg, 1849, pp. 63, 64. Hustedt, 1929, p. 471, fig. 262. Brown, 1933, p. 55, pl. 4, fig. 5. Cupp, 1943, p. 66, fig. 28, pl. 4, fig. 1.

Geologic range. Late Cretaceous to Recent.

Ecology. This species "favours tropical and subtropical waters," and it is a "littoral diatom; it probably spends part of its time as a bottom form, epiphytic often upon red algae and corallines; sometimes found in large numbers," according to Hendey (1937, p. 267).

Arachnoidiscus evanescens Brown.

(Figure 61.)

Arachnoidiscus ehrenbergii var. *evanescens* Grunow, *in* Schmidt, 1881, pl. 68, fig. 7 [stated "Monterey (Grunow), nach Grunow, der übrigens auch *A. indicus* nur als *A. Ehrenbergii* var. *gelten* las will, *A. Ehrenbergii* var. *evanescens*. . . . für *A. indicus* var. *nehmen*."]

Arachnoidiscus evanescens Brown, 1933, p. 74.

Geologic range. Late Miocene.

Remarks. It is distinguished from *A. decorus* Brown by its broader rays, and the cells are not sunk in pits.

Arachnoidiscus ornatus var. **montereyanus** Schmidt.

(Figures 62, 63.)

"*Arachnoidiscus ornatus* var. *montereiana* A.S.," 1882, pl. 73, figs. 8, 9. Brown, 1933, p. 50.

Not *Arachnoidiscus ornatus* var. *montereiana* A.S., 1882, pl. 73, fig. 7.

Not *Arachnoidiscus manni* Hanna and Grant, 1926, p. 125, pl. 12, figs. 7-9.

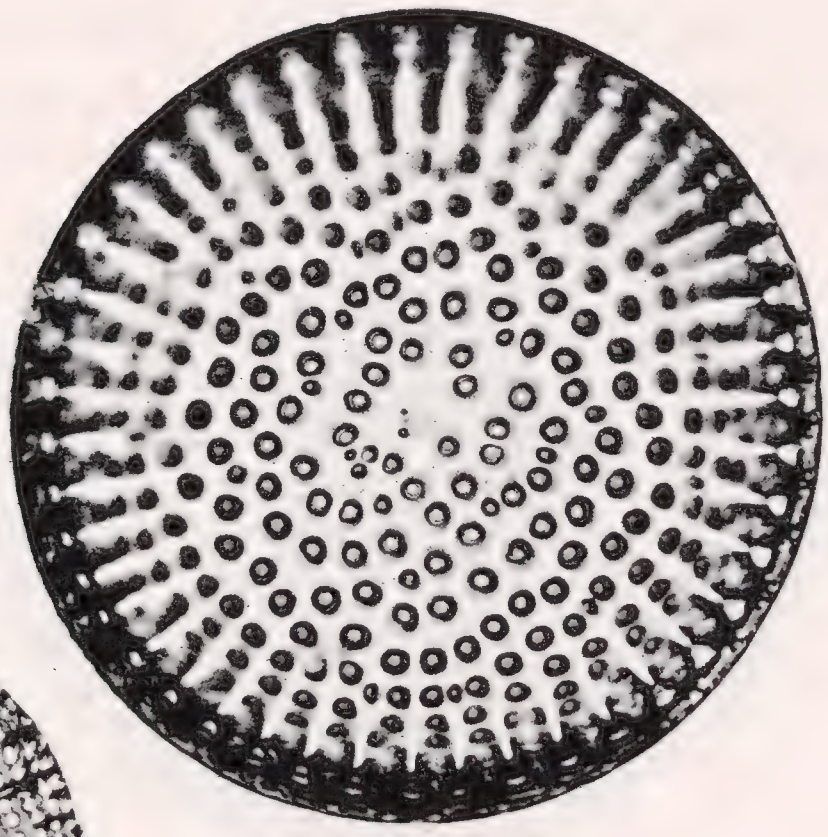
Figure 53. *Arachnoidiscus decorus* Brown. Hypotype no. 3946 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.1410 mm.

Figure 54. *Stictodiscus californicus* Greville. Hypotype no. 3707 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.1300 mm.

Figure 55. *Stictodiscus californicus* Greville. Hypotype no. 3708 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.1600 mm.

Figure 56. *Arachnodiscus ehrenbergii* Bailey. Hypotype no. 3709 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.1901 mm.

Figure 57. *Arachnoidiscus ehrenbergii* Bailey. Hypotype no. 3710 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.2240 mm.



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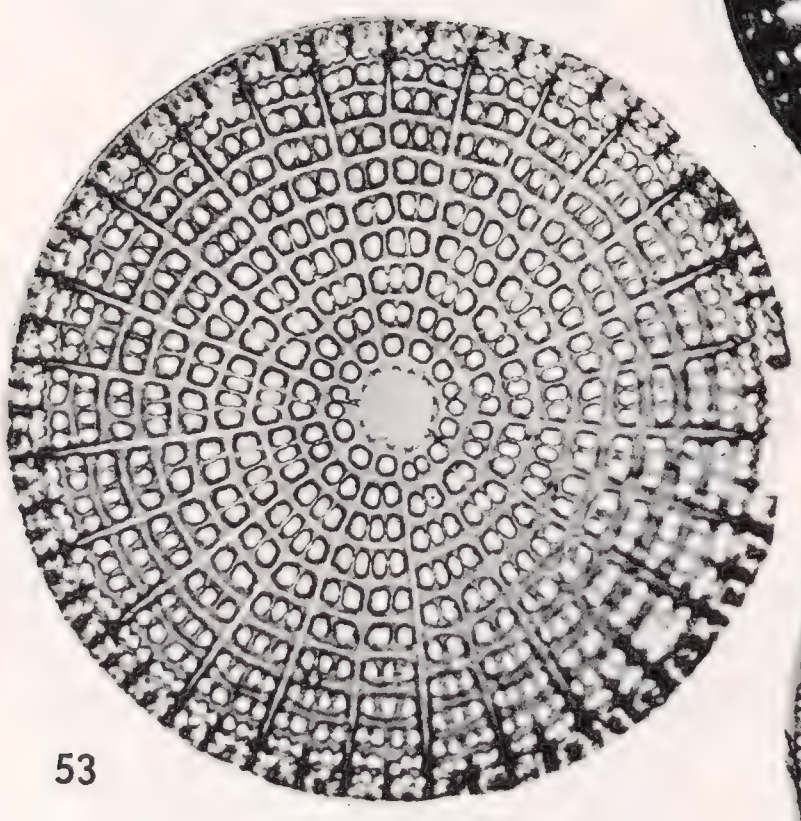

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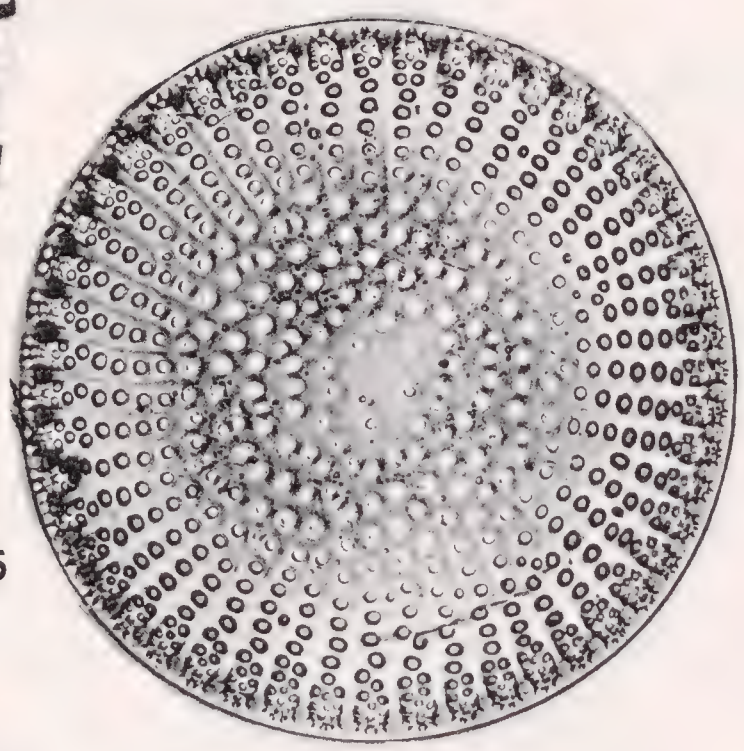

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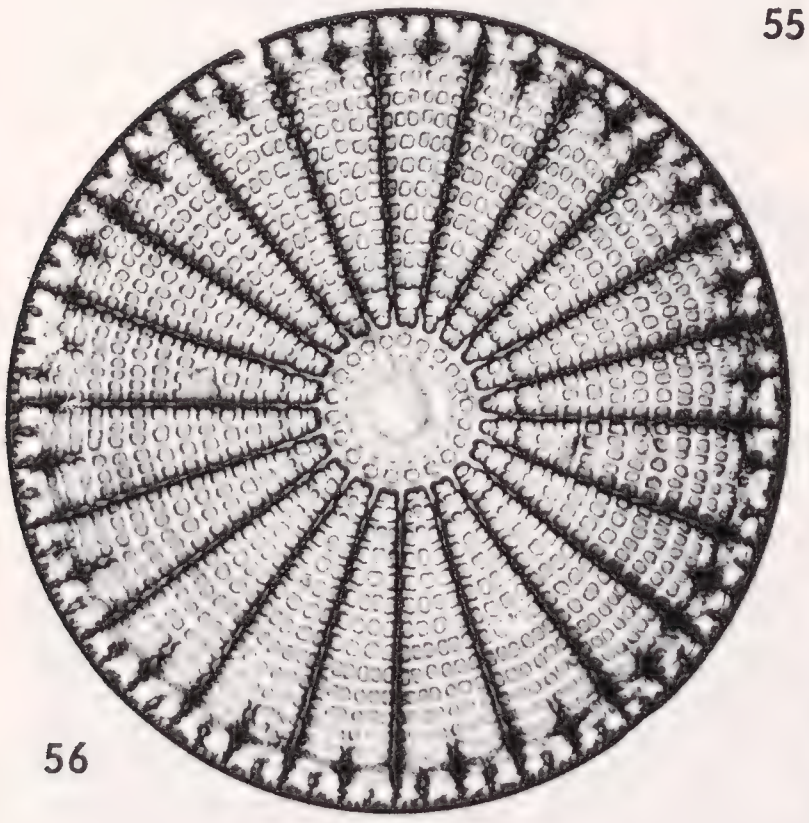

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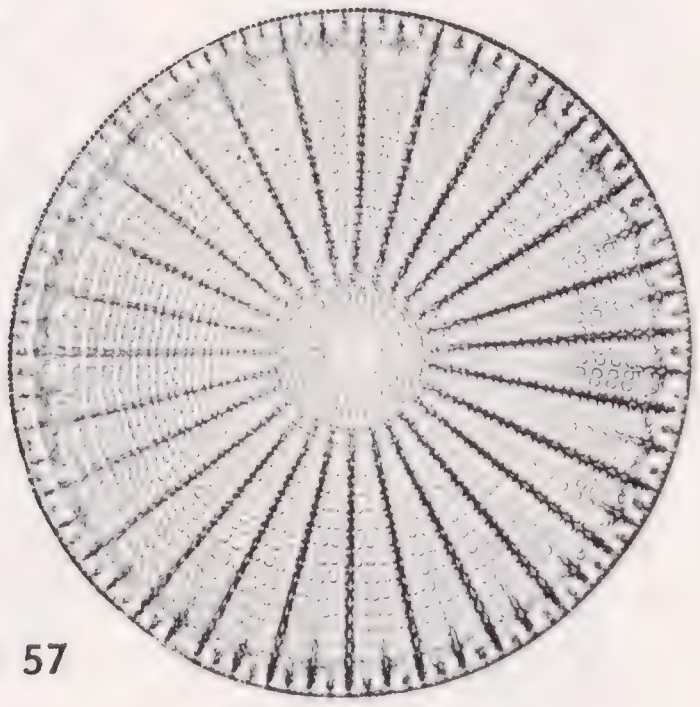

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Geologic range. Middle Miocene to late Miocene.

Remarks. This variety is distinguished from the typical species by having the greater portion of the valve surface covered with an irregular network of dark lines.

Genus **Cladogramma** Ehrenberg, 1844.

Cladogramma californicum Ehrenberg.

(Figure 64.)

Cladogramma californicum Ehrenberg, 1854, pl. 33, no. 13, fig. 1. Van Heurck, 1882, pl. 83 bis, figs. 18, 19.

Geologic range. Late Miocene.

Subfamily Actinoptychoideae Schütt, 1896 [12e, 12f]

Genus **Actinoptychus** Ehrenberg, 1843

Actinoptychus bismarckii Schmidt.

(Figure 65.)

Actinoptychus bismarckii Schmidt, 1886, pl. 91, fig. 4. Wolle, Diatomaceae of North America, 1894, pl. 103, fig. 3. De-Toni, Sylloge Algarum, 1894, p. 1389.
Actinoptychus astur Brun, Hanna, 1951, p. 284, fig. 3, no. 4.

Geologic range. Late Miocene.

Remarks. Valves discoid, with six radial compartments, alternately raised and depressed. The raised compartment with very coarse square to polygonal areolation, usually in parallel rows from the central hyaline area to the narrow margin. The depressed compartments have parallel rows of areolae.

Figure 58. *Arachnoidiscus ehrenbergii* Bailey. Hypotype no. 3711 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.1901 mm.

Figure 59. *Arachnoidiscus ehrenbergii* Bailey. Hypotype no. 3712 (CAS), from locality 27295-155 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Diameter 0.1828 mm.

Figure 60. *Arachnoidiscus ehrenbergii* Bailey. Hypotype no. 3713 (CAS), from locality 27295-155 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Diameter 0.2192 mm.

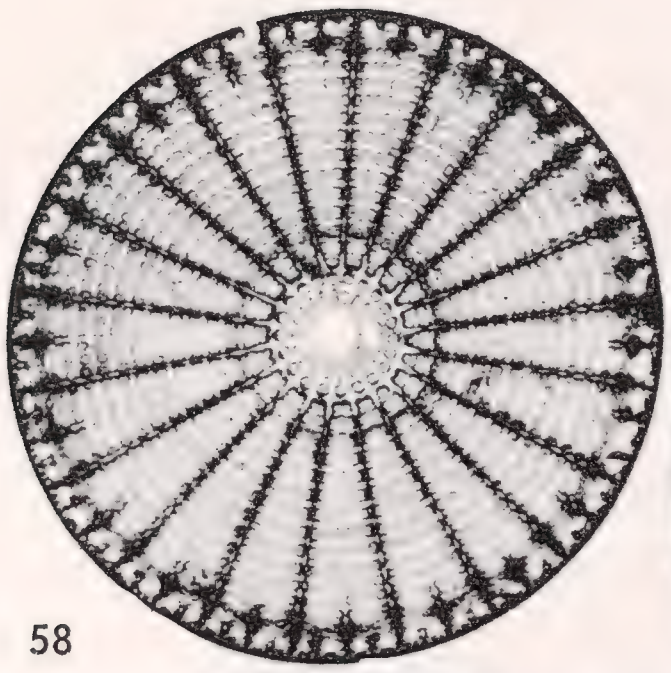
Figure 61. *Arachnoidiscus evanescens* Brown. Hypotype no. 3714 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.1260 mm.

Figure 62. *Arachnoidiscus ornatus* var. *montereyanus* Schmidt. Hypotype no. 3715 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.3120 mm.

Figure 63. *Arachnoidiscus ornatus* var. *montereyanus* Schmidt. Hypotype no. 3716 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.2480 mm.

Figure 64. *Cladogramma californicum* Ehrenberg. Hypotype no. 3717 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.0303 mm.

12e Schütt, 1896, p. 55, as subtribe Actinoptychinae.
12f Hustedt, 1930, p. 56, new status and change in spelling.



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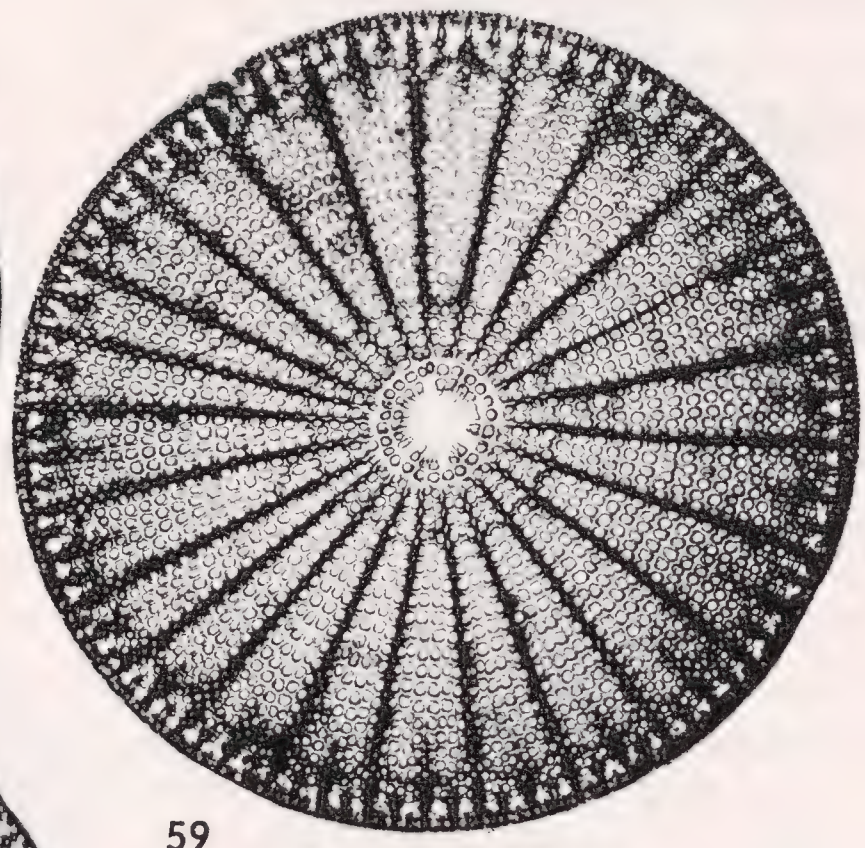

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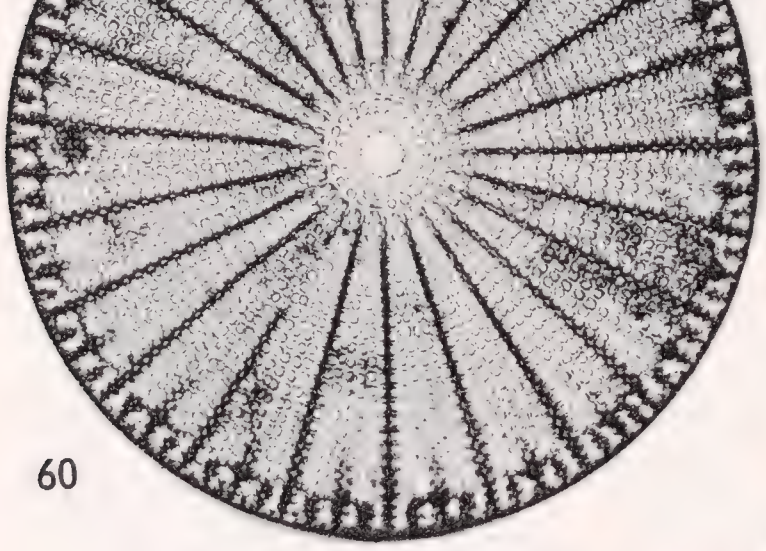

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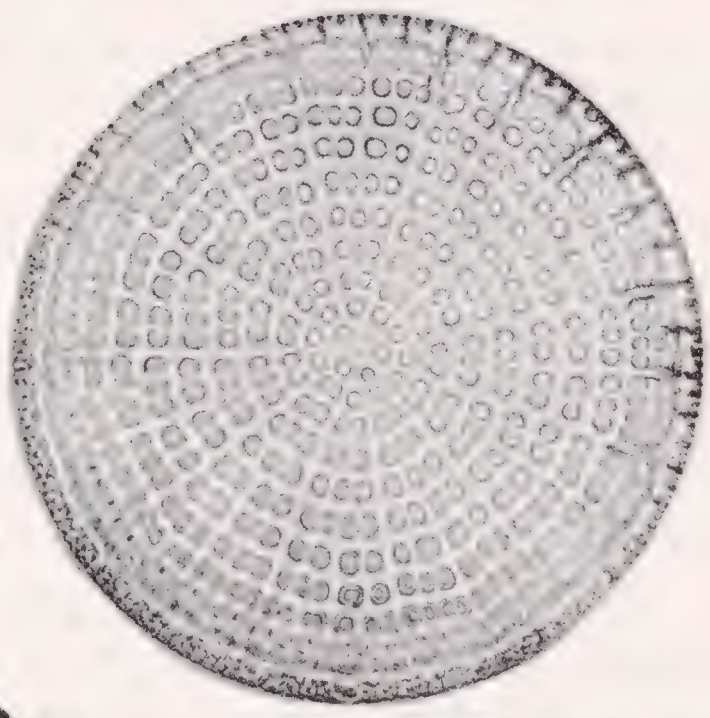

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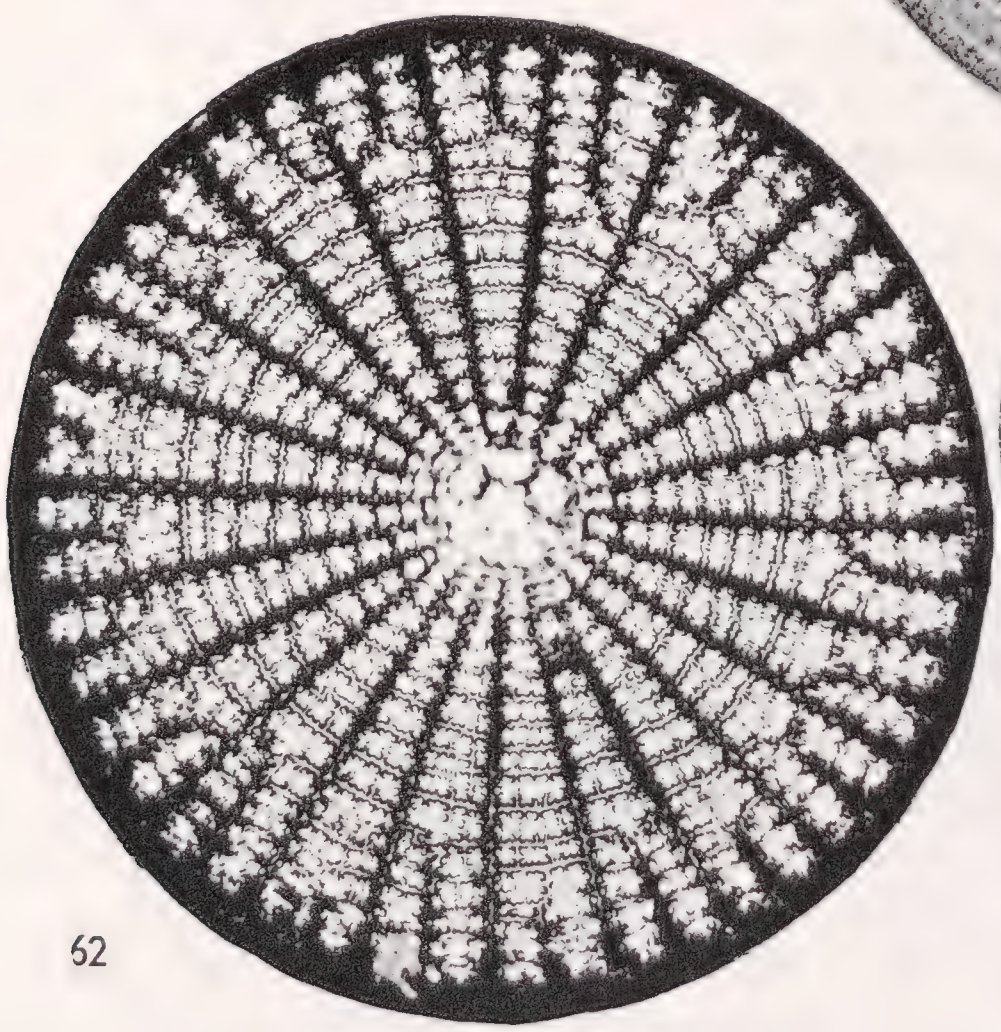

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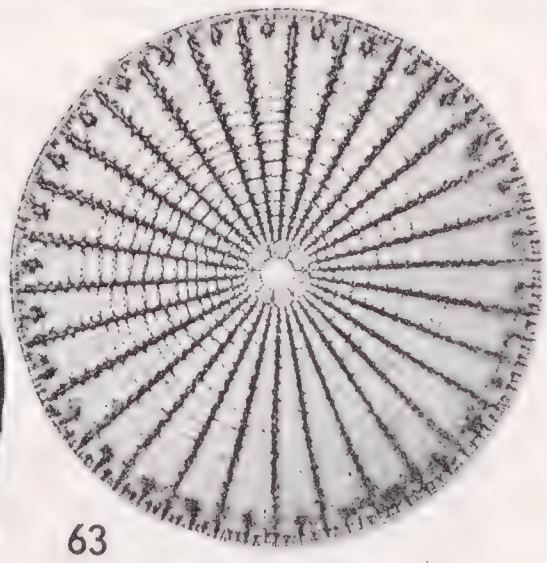

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Actinoptychus gründleri Schmidt.

(Figure 66.)

Actinoptychus gründleri Schmidt, 1874, pl. 1, fig. 22. Pantocsek, 1886, pl. 12, fig. 106; 1889, pl. 25, fig. 365. Wolle, 1894, pl. 92, figs. 3, 7. Schmidt, 1886, pl. 90, fig. 7.
Actinoptychus stella Schmidt, 1886, pl. 90, fig. 1.
Actinoptychus gallegosi Hanna and Grant, 1926, p. 120, pl. 11, fig. 6.
Actinoptychus pfitzeri Gründler, *in* Schmidt, 1875, pl. 29, fig. 1.

Geologic range. Eocene to Miocene.

Actinoptychus senarius Ehrenberg.

(Figure 67.)

Actinocyclus senarius Ehrenberg, 1838, p. 172, pl. 21, fig. 6.
Actinoptychus senarius Ehrenberg, 1841, p. 400, pl. 1, gr. 1, fig. 27; pl. 1, gr. 3, fig. 22 [fig. 21], [1843]. Hendey, 1937, p. 271. Lohman, 1941, p. 80, pl. 16, fig. 9. Hendey, 1964, p. 95.
Actinoptychus undulatus Ehrenberg. Schmidt, 1875, pl. 1, figs. 1-4, 6; 1886, pl. 109, fig. 1; 1888, pl. 132, fig. 16; 1890, pl. 153, fig. 25.
Actinoptychus undulatus (Bailey) Ralfs. Hanna and Grant, 1926, p. 124, pl. 12, fig. 4. Hustedt, 1929, p. 475, fig. 264.

Geologic range. Late Cretaceous to Recent.

Ecology. "Neritic, Bottom form. Frequently found in plankton. Of very wide distribution," according to Cupp (1943, p. 67). "Im Küstengebiet, selten im Küstenplankton, aller Meere verbreitet und häufig, auch hier und da in die Flussmündgungen hineingehend. Im Mittelmeergebiet weniger zahlreich als an den nördlichen Küsten Mitteleuropas," stated by Hustedt (1930, p. 476).

"This species is widely spread throughout north temperate seas and frequently is found in the plankton of deep water. It is very variable in appearance and size. The distribution of the areoles and the fineness of the

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Figure 65. *Actinoptychus bismarckii* Schmidt. Hypotype no. 3718 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.1075 mm.

Figure 66. *Actinoptychus gründleri* Schmidt. Hypotype no. 3719 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.2340.

Figure 67. *Actinoptychus senarius* Ehrenberg. Hypotype no. 3720 (CAS), from locality 27295-7 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Diameter 0.0444mm.

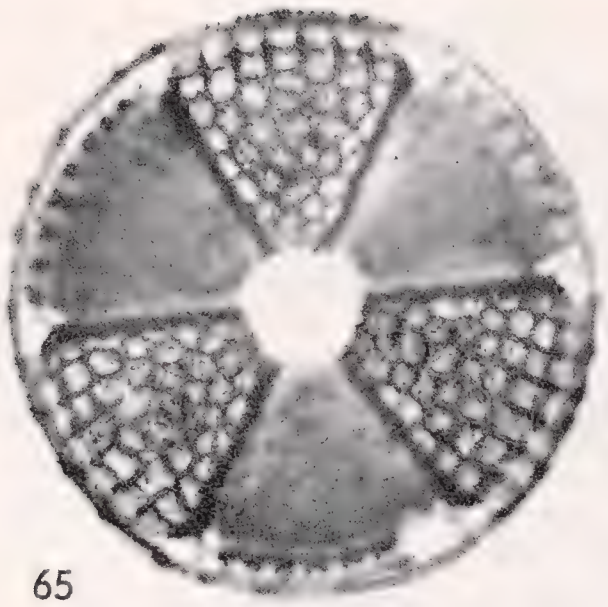
Figure 68. *Actinoptychus splendens* var. *incisa* (Grunow), new combination. Hypotype no. 3721 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.0510 mm.

Figure 69. *Actinoptychus splendens* var. *incisa* (Grunow), new combination. Hypotype no. 3722 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.0820 mm.

Figure 70. *Actinoptychus splendens* var. *incisa* (Grunow), new combination. Hypotype no. 3723 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.0940 mm.

Figure 71. *Actinoptychus splendens* var. *incisa* (Grunow), new combination. Hypotype no. 3724 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.1680 mm.

Figure 72. *Actinoptychus splendens* var. *angelorum* (Grunow), new combination. Hypotype no. 3724a (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.105 mm.



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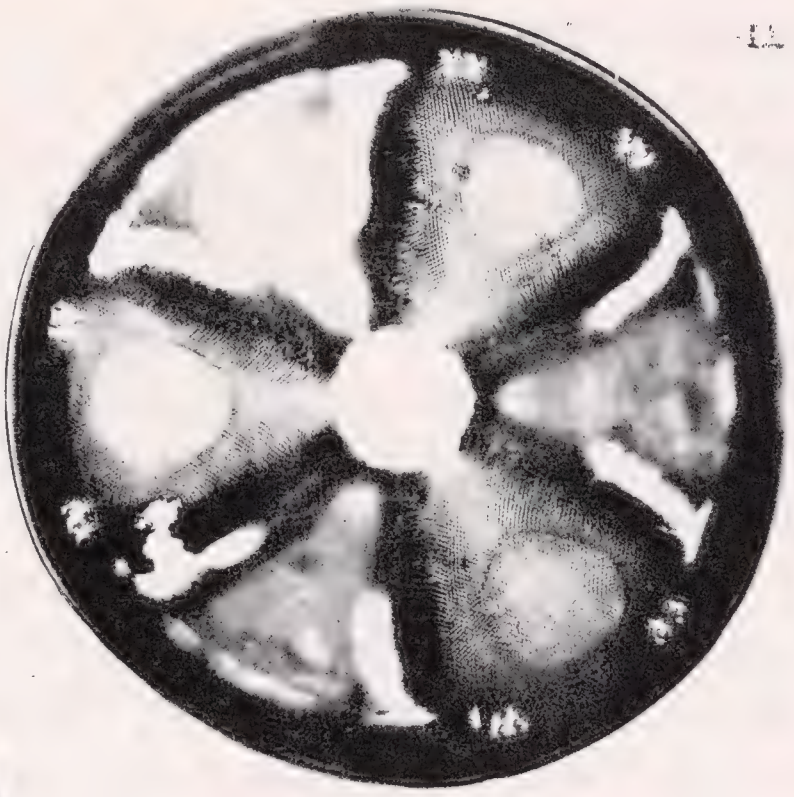

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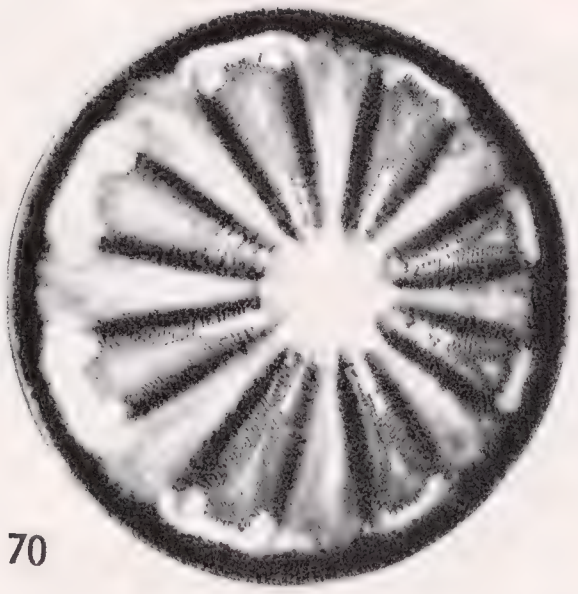

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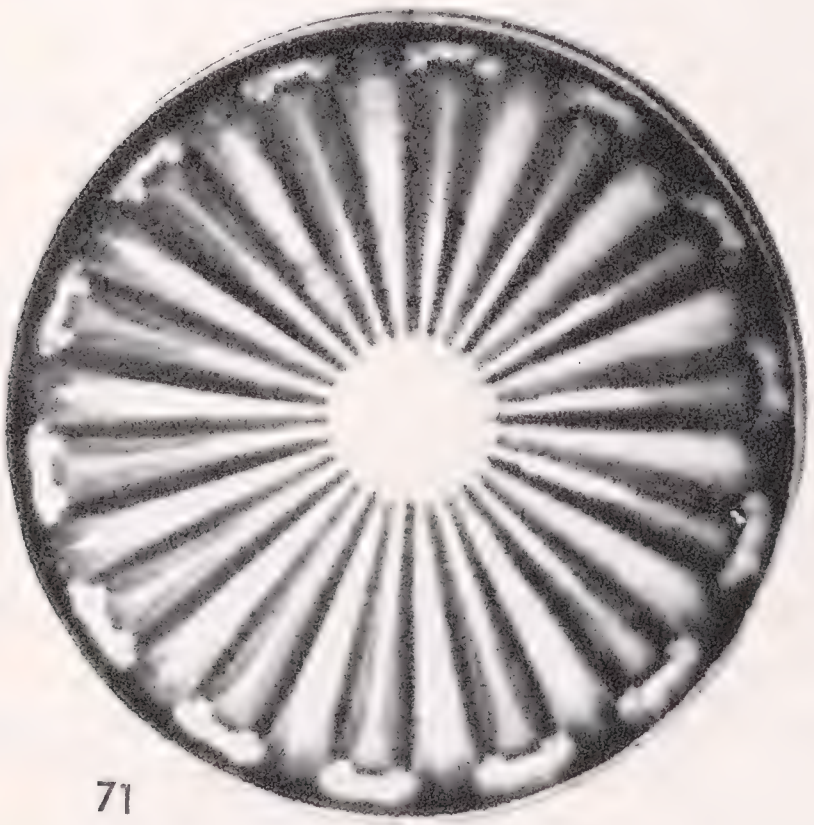

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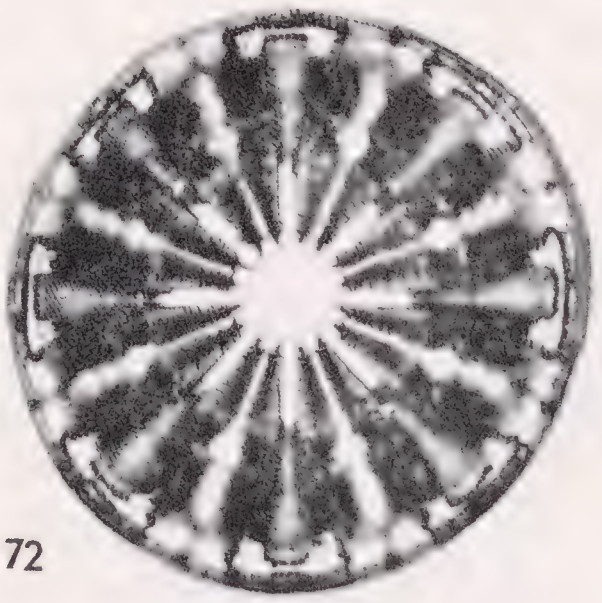

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markings varies almost from specimen to specimen," according to Hendey (1951, p. 32). Also, as stated by Hendey (1964, p. 95): "This species is cosmopolitan; it is widely spread throughout north temperate seas and common in the neritic plankton all around British coasts. Common also in oceanic plankton. It is never abundant but it is hardly ever absent from littoral gatherings taken at almost any time during the year."

Remarks. Valves discoid, with mostly six radial sectors, alternately raised and depressed. The raised sectors with short but stout processes (apicules) in the middle of the sector and at the inner edge of the margin. Sectors with coarse polygonal areolation. Secondary structure of fine puncta upon the inner surface of the areoles. Margin finely striate, with a ring of fine spinulae. Central space hyaline usually hexagonal. Considerable variation. Diameter of valves ranges from 0.0270 mm. to 0.0660 mm.

It is of interest to note that Hendey's proposal (1937) to reinstate the valid name *A. senarius* Ehrenberg, was also proposed in 1854 by Roper, p. 73.

Actinoptychus senarius var. **minutus** (Greville).

Actinoptychus minutus Greville, 1866, p. 5, pl. 1, fig. 12. Truan y Luard and Witt, 1888, p. 11, pl. 2, fig. 24.
Actinoptychus minutus Greville fa. *major* Forti, 1913, pp. 1587-1589, pl. 5, fig. 3.
Actinoptychus undulatus Ehrenberg, Schmidt, 1888, pl. 132, fig. 16.

Geologic range. Late Miocene to Pliocene.

Remarks. Valves discoid, usually with eight compartments alternate-

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Figure 73. *Actinoptychus splendens* var. *incisa* (Grunow), new combination. Hypotype no. 3725 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.160 mm.

Figure 74. *Actinoptychus splendens* var. *solisi* Hanna and Grant. Hypotype no. 3726 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.1300 mm.

Figure 75. *Actinoptychus splendens* var. *solisi* Hanna and Grant. Hypotype no. 3727 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.1300 mm.

Figure 76. *Actinoptychus splendens* var. *solisi* Hanna and Grant. Hypotype no. 3728 (CAS), from locality 27295-25 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Diameter 0.0754 mm.

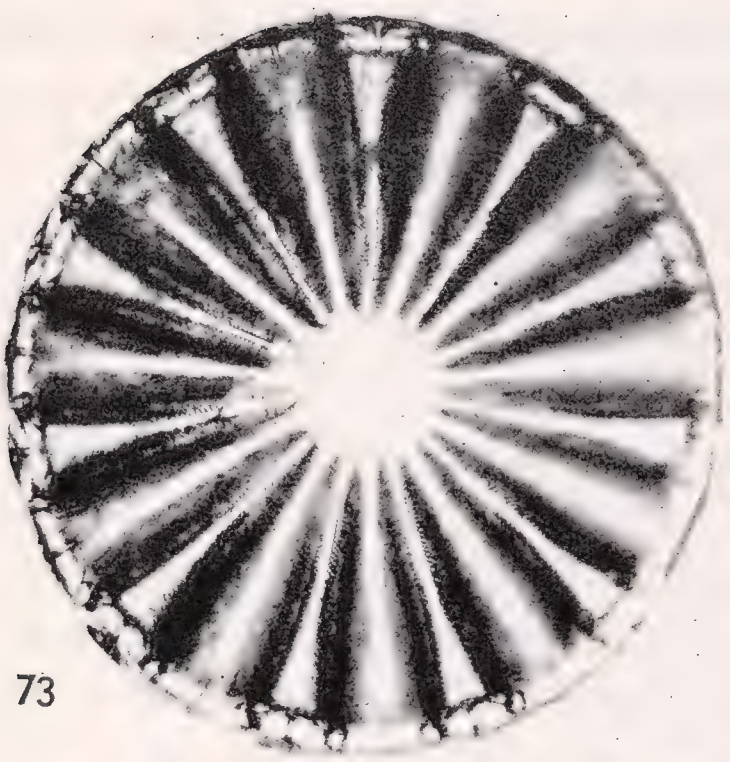
Figure 77. *Actinoptychus splendens* var. *solisi* Hanna and Grant. Hypotype no. 3729 (CAS), from locality 27295-7 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Diameter 0.0470 mm.

Figure 78. *Actinoptychus stella* var. *clevi* (Schmidt), new combination. Hypotype no. 3730 (CAS), from locality 27295-102 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Diameter 0.0820 mm.

Figure 79. *Actinoptychus vulgaris* var. *monicae* Grunow. Hypotype no. 3731 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.0810 mm.

Figure 80. *Actinoptychus vulgaris* var. *monicae* Grunow. Hypotype no. 3732 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.1080 mm.

Figure 81. *Actinoptychus vulgaris* var. *monicae* Grunow. Hypotype no. 3733 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.1800 mm.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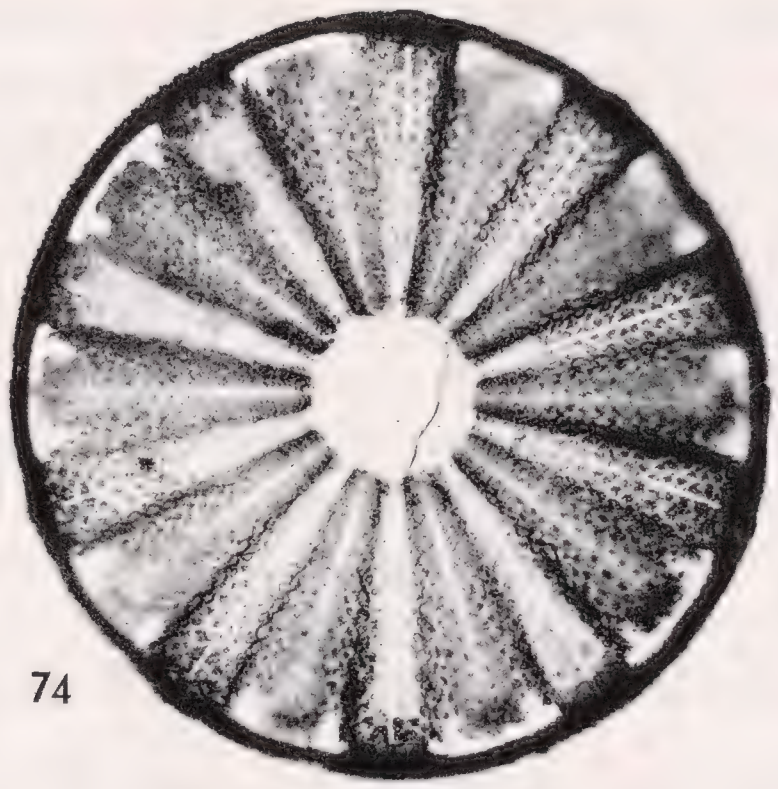
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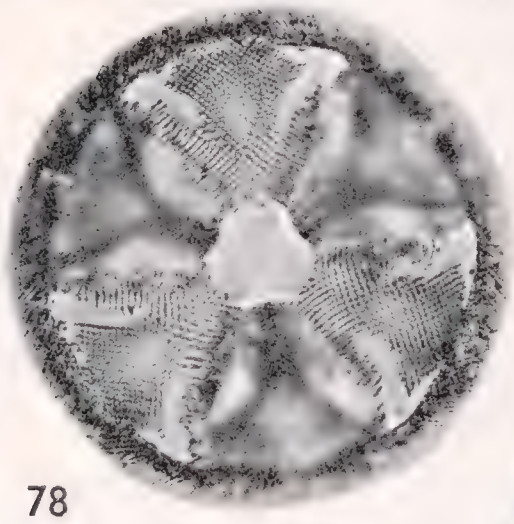
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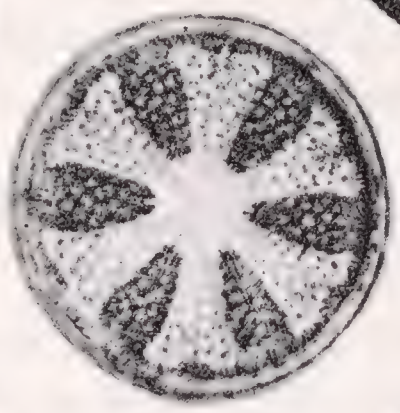
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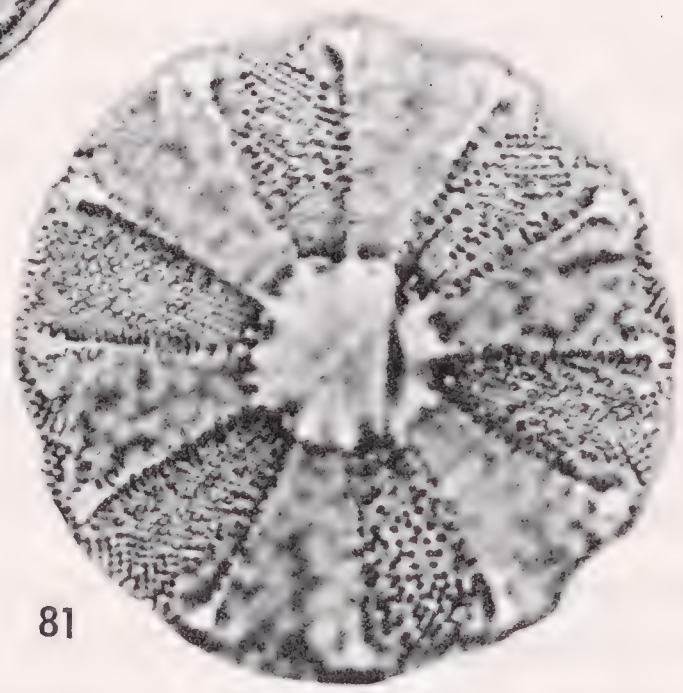
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ly slightly raised and depressed. A central hyaline area with a cross can be seen if properly focused, which is characteristic of this variety.

Actinoptychus splendens var. **angelorum** (Grunow), new combination.

(Figure 72.)

Actinoptychus glabratus var. angelorum Grunow, *in* Van Huerck, 1883, pl. 120, fig. 9.

Geologic range. Late Miocene.

Remarks. Valves discoid, with alternately raised and depressed compartments, characterized by narrow hyaline spaces running from the central area to the inner margin and ending in a spine. In alternate compartments somewhat narrow hyaline spaces extend half way to the margin, the compartments ending in a pseudo-bracket-shaped hyaline area.

Actinoptychus splendens var. **incisa** (Grunow), new combination.

(Figures 68-71, 73.)

Actinoptychus incisa Grunow, *in* Schmidt, 1890, pl. 154, figs. 2, 3. Hanna and Gaylord, 1925, pl. 4, fig. 11.

Geologic range. Late Miocene to Pliocene.

Remarks. There is a complete intergradation of these forms.

Actinoptychus stella var. **clevei** (Schmidt), new combination.

(Figure 78.)

Actinoptychus clevei Schmidt, 1886, pl. 91, fig. 1. Aspeitia, 1911, p. 184, pl. 8, fig. 7.

Geologic range. Late Miocene.

Remarks. The little difference between the typical species of *A. stella* and *A. clevei* Schmidt is not of the specific magnitude, and so I have placed it as a variety of the species *A. stella*.

Actinoptychus splendens var. **solisi** Hanna and Grant.

(Figures 74-77.)

Actinoptychus solisi Hanna and Grant, 1926, p. 123, pl. 12, figs. 1-3.
Actinoptychus halionyx Grunow, Hanna, 1932, p. 169, pl. 2, fig. 4.
Actinoptychus splendens var. *halionyx* Grunow, *in* Van Heurck, 1883, pl. 119, fig. 3; pl. 120, figs. 3,5.
Actinoptychus splendens var. *californica* Grunow, *in* Van Heurck, 1883, pl. 120, fig. 1.

Geologic range. Middle Miocene to Recent.

Ecology. "Wie die vorige Art im Küstengebiet aller Meere verbreitet und häufig. Die Varietät findet such lier und da unter der Art, besonders im Mittelmere," according to Hustedt (1929. p. 479).

Remarks. Valves discoid, alternately raised and depressed compartments; the raised sectors with a narrow hyaline line extending from the round hyaline central area to the margin of the valve and ending in a short spine. The areolation in the raised sectors is fairly strong. The depressed

sectors with bracket-shaped hyaline areas near the margin. These individuals compare closely with the Maria Madre Island specimens.

Shadbolt (1854, Trans. Mic. Soc., p. 16) described *Actinophaenia splendens,* new genus and species as follows: "There is a very striking and beautiful discoid valve, tolerably abundant, of the same genus as one commonly found in the guano from Callao, but which, I conceive, as never yet had a generic name. It differs in essential characters both from the *Coscinodiscus* and *Actinocyclus,* and its position would probably be midway between them."

"It possesses a pseudonucleus, is minutely embellished with delicate markings similar to those seen in *Pleurosigma angulatum,* but in segments radiating from the center, so that, in all probability, the front view would exhibit slight undulations. The absence of any distinct division between the segments, however, separates it from *Actinocyclus.* I propose for this form the generic name *Actinophaenia*...glittering, with the specific designation *splendens.*"

In the same volume, Roper discussed a form he found in the Thames, and says (p. 72): "Sparingly distributed, I have another large and beautiful disc (fig. 2) with sixteen septa, the surface of which is covered with faint cross striae, similar to those of *Pleurosigma;* and in that respect it resembles the valves from Natal, for which Mr. Shadbolt proposed the name of *Actinophaenia;* but I find this striation is no distinctive character, as all the specimens of *A. undulatus* (or *senarius)* that I have examined have the same peculiarity, and the septa are plainly discernible, especially with the parabolic condenser. In the lists I have applied to it provisionally the name of *Actinocyclus sedenarius,* as it approaches very nearly to Ehrenberg's figure of that species in the 'Berlin Transactions' for 1839, tab. 4, p. 2. The septa appear to have their origin from the smooth central portion or pseudo-nodule, and to terminate at slight elevations or openings at the margin of the disc, and in perfect specimens, those on one valve are opposite to the interspaces on the other. The front view exhibits slight traces of undulations, as in fig. 13, not in continuous wave lines, but rising to points at the extremities of the rays, giving the side view an appearance similar to that of a ridge-and furrow roof. The diameter varies from 1-288th to 1-187th of an inch."

Then Brightwell (1860, p. 94) stated: "19. *Actinophaenia splendens,* shadbolt. - Valve with two plates, one with very fine oblique markings, the other with much coarser markings, arranged in a somewhat pinnate manner. (Pl. VI, fig. 15) [18]."

A common species, varying greatly in size and number of segments. Brick fields, Caermarthen, Mr. Okeden. Very fine. Syn. —*Actinocyclus octodenarius,* and numerous other species of Ehrenberg: —*Actinocyclus duodenarius, sedenarius, octodenarius. Actinocyclus sedenarius,* Roper ('Micr.

Journ.,' vol. ii, pl. VI, fig. 2). --Mr. Roper's figure is unsatisfactory, giving only the fine markings. (Smith, "Syn. Brit. Diat.,' vol. ii, Appendix, p. 86). Professor Smith has published, with doubts as to their distinctness, the three species named above, which are certainly only varieties. It is unfortunate that he should have transferred these names from the genus *Actinoptychus*, in which they were placed by Ehrenberg, to that of *Actinocyclus*, thus creating the greatest confusion. Ehrenberg's *Actinoptychus duodenarius, sedenarius, bioctodenarius*, we believe to be totally different from the form in question."

A year later, Ralfs in Pritchard (1861, Infusoria, p. 849) described *A. splendens* (Shadbolt) as a species of *Actinoptychus*, as follows: "*A. splendens* (Shadbolt). - Compartments (12-20) obscurely cellulose, each with a median line, which terminates in a clavate intramarginal nodule or tooth; umbilicus hyaline, definite. =*Actinophaenis splendens*, Sh TM. iil p. 16; *Actinoptychus sedenarius*, E., Ro TM. ii. p. 74, pl. 6, f. 2. Common. Guano, England. In this species the alternate depressions of the compartments are often very slight; and the compartments being striated, frequently appear irregular, and are counted with difficulty. The species nevertheless has so peculiar an aspect that once known it is easily recognized. The rays are most distinct where they radiate from the hyaline umbilicus, at which part they sometimes appear thickened. In some specimens the nodules are confined to the alternate compartments."

The entire mix-up was supposed to be cleared up by Hustedt (1929, p. 478, fig. 265) by lumping *Actinophaenia splendens* Shadbolt, *Actinoptychus sedenarius* Ehrenberg, *Actinoptychus quatuordenarius* Ehrenberg, *Halionyx quinarius, senarius, septenarius, octonarius, nonarius, denarius, undenarius, vicenarius*, Ehrenberg, *Actinoptychus halionyx* Grunow, *Actinoptychus glabratus* Grunow, *Actinoptychus janischii* Grunow.

I question the validity of Hustedt's lumping because of Brightwell's (1890, p. 94) statement that: "Ehrenberg's *Actinoptychus duodenarius, sedenarius, bioctodenarius*, we believe to be totally different from the form in question." [which was *Actinophaenia splendens*, Shadbolt, who first described this species].

Also Mann (1907, p. 271) stated in a footnote "b", in regard to *Actinophaenia splendens* Shadbolt: "This name was originally published by Shadbolt in Trans. Micr. Soc. Lond. n.s. 2:16. 1854. The description is insufficient for a determination, but Brightwell's identification may be correct, inasmuch as he was contemporary worker and may have seen authentic material."

I have used the name *solisi* as a variety name for the form called *A. halionyx* because I do not think the variety name *halionyx* Grunow is valid. According to Hustedt (1929, p. 478), the original form of *Actinoptychus halionyx* Grunow is a synonym of *Actinoptychus splendens* (Shadbolt).

Grunow later illustrated a form which he called *Actinocyclus splendens* var. *halionyx* which was not the same as his original *A. halionyx* species. Therefore, in order to retain the variety *halionyx*, I have used the name *solisi* of Hanna and Grant in place of *A. halionyx*.

Actinoptychus vulgaris var. **monicae** Grunow.

(Figures 79-81.)

Actinoptychus vulgaris var. *monicae* GRUNOW, *in* Van Heurck, 1883, pl. 121, fig. 9; WOLLE, 1890, pl. 85, fig. 20.

GEOLOGIC RANGE. Late Miocene.

REMARKS. Valves discoid, with alternately raised and depressed compartments, the raised ones with one spine at the margin. Areolae well developed central hyaline area takes various shapes.

This variety is especially characterized by the hyaline spaces that are present in the depressed compartments at the margin of the valve. These are usually not connected. When properly focused, these depressed sectors appear to have many small beads submarginal and decrease toward the central hyaline area.

Subfamily ASTEROLAMPROIDEAE H. L. Smith, 1872 [12g, 12h]

Genus **Asteromphalus** Ehrenberg, 1844

Asteromphalus arachne (Brébisson) Greville.

Spatanidium arachne BRÉBISSON, 1857, p. 296, pl. 3, fig. 1.
Asteromphalus arachne (Brébisson) GREVILLE, 1860, p. 123.
Asteromphalus arachne Brébisson. SCHMIDT, 1876, pl. 38, fig. 4.

GEOLOGIC RANGE. Pliocene.

Asteromphalus brookei Bailey.

Asteromphalus brookei BAILEY, 1856, p. 2, pl. 1, fig. 1. SCHMIDT, 1876, pl. 38, figs. 21-23. RATTRAY, 1890, p. 209.

GEOLOGIC RANGE. Late Miocene to late Pliocene.

REMARKS. This species is characterized by compartments with inner ends obtusely rounded or truncate. The rays may be simple and the geniculations are not regular.

Asteromphalus darwinii Ehrenberg.

(Figure 82.)

Asteromphalus darwinii EHRENBERG, 1844, p. 200, pl. (June), fig. 1. GREVILLE, 1860, p. 116, pl. 4, figs. 12, 13.

GEOLOGIC RANGE. Late Miocene.

12g H. L. Smith, 1872, p. 17, as family Asterolampreae.

12h De-Toni, 1890, p. 919, new status and change in spelling.

Suborder Aulacodiscineae Hendey, 1937 [12i]

Family Eupodiscaceae Kützing, 1844 [12j, 12k]

Subfamily Aulacodiscoideae Pantocsek, 1886 [12l, 12m]

Genus **Aulacodiscus** Ehrenberg, 1845

Aulacodiscus brownei Norman.

(Figure 84.)

Aulacodiscus brownei Norman, *in* Pritchard, 1861, p. 844. Rattray, 1888, p. 341. Hanna, 1932, p. 175, pl. 5, fig. 3.

Geologic range. Middle Miocene to Pliocene.

Aulacodiscus concentricus (Mann) Boyer.

(Figure 83.)

Tripodiscus concentricus Mann, 1907, p. 278, pl. 54, figs. 1, 2.
Aulacodiscus concentricus (Mann) Boyer, 1926, p. 76.

Geologic range. Late Miocene.

Remarks. Distinguished from *A. brownei* by its more concentric markings.

Aulacodiscus cornutus Brun.

Aulacodiscus cornutus Brun, *in* Schmidt, 1882, pl. 170, fig. 2.

Aulacodiscus crux Ehrenberg.

Aulacodiscus crux Ehrenberg, 1844, p. 76. Boyer, 1926, p. 76. Wolle, 1894, pl. 88, fig. 1.

Aulacodiscus kittoni Arnott.

Aulacodiscus kittoni Arnott, *in* Pritchard, 1861, p. 844, pl. 8, fig. 24. Hustedt, 1929, pp. 506-509, fig. 283. Cupp, 1943, p. 70, fig. 33, pl. 8, fig. 24.

Geologic range. Late Miocene to Recent.

Ecology. This species occurs in the littoral zone and is occasionally found in the plankton, according to Cupp (1943, p. 70).

Remarks. The large rosette in the center portion of the valve surface is one of the most characteristic features of this species.

[12i] Hendey, 1937, p. 203.

[12j] Kützing, 1844, p. 137, as family Eupodisceae.

[12k] De-Toni, 1890, p. 916, new status and change in spelling.

[12l] Pantocsek, 1886, p. 55, as family Aulacodisceae.

[12m] Hustedt, 1930, p. 56, new status and change in spelling.

Aulacodiscus margaritaceus Ralfs.

Aulacodiscus margaritaceus RALFS, *in* Pritchard, 1861, p. 844. SCHMIDT, 1876, pl. 37, figs. 4-7; 1886, pl. 92, fig. 12; 1886, pl. 105, figs. 1-2, 4. RATTRAY, 1888, p. 351, pl. 6, fig. 3.

GEOLOGIC RANGE. Late Miocene to Recent.

Aulacodiscus simplex Rattray.

(Figure 85.)

Aulacodiscus simplex RATTRAY, 1888, p. 340.

Aulacodiscus decorus GREVILLE. SCHMIDT, 1876, pl. 33, fig. 9.

GEOLOGIC RANGE. Late Miocene.

Suborder AULISCINEAE Hendey, 1937 [12n]

Family AULISCACEAE Hendey, 1937 [12n]

Subfamily AULISCOIDEAE Heiden-Kolbe, 1928 [13, 14]

Genus **Auliscus** Ehrenberg, 1844

Auliscus albidus Brun.

(Figure 86.)

Auliscus albidus BRUN, *in* Schmidt, 1882, pl. 171, figs. 3, 4.
Auliscus albidus var. *baccata* BRUN, *in* Schmidt, 1882, pl. 171, fig. 5.

GEOLOGIC RANGE. Late Miocene.

Auliscus caelatus Bailey.

(Figure 87.)

Auliscus caelatus BAILEY, 1854, p. 6, pl. 1, figs. 3, 4. SCHMIDT, 1875, pl. 32, figs. 14, 15. RATTRAY, 1888, p. 25. HANNA AND GRANT, 1926, p. 129, pl. 13, fig. 8. HUSTEDT, 1928, p. 518, fig. 291.

GEOLOGIC RANGE. Late Miocene to Recent.

ECOLOGY. According to Hustedt (1928, p. 521), "Die Art ist zwar im ganzen europäischen Meeresgebiet verbreitet, aber viel seltener als *Aul. sculptus.*"

Auliscus caelatus var. **constricta** Rattray.

(Figures 88-91, 95.)

Auliscus caelatus var. *constricta* RATTRAY, 1888, p. 27, pl. 15, fig. 8. HUSTEDT, 1928, p. 519, fig. 293.

GEOLOGIC RANGE. Late Miocene to middle Pliocene.

12n Hendey, 1937, p. 203.

13 Heiden-Kolbe, 1928, p. 463, as a tribe Aulisceae.

14 Hendey, 1937, p. 203, new status and change of spelling.

Auliscus grunowi var. **californica** Grunow.

(Figures 92-94.)

Auliscus grunowi var. *californica* Grunow, *in* Schmidt, 1886, pl. 89, fig. 8; 1944, pl. 454, figs. 8, 9.
Auliscus grunowii var. *californica* Grunow, Rattray, 1888, p. 872.

Geologic range. Late Miocene.

Ecology. According to Hustedt (in Schmidt, 1944, pl. 454, figs. 8, 9), "Ich mache auf die Divergenz der radialen Streifen in den beiden Feldern der Querarea aufmerksam, während diese Punktreihen bei *Aul. pruinosus* von der Peripherie gegen das Zentrum stark konvergieren!"

Auliscus hardmanianus Greville.

Auliscus hardmanianus Greville, 1866, p. 6, pl. 2, 17. Rattray, 1888, p. 877. Schmidt, 1881, pl. 67, fig. 1; 1886, pl. 108, fig. 1. Mann, 1907, p. 282.

Geologic range. Late Miocene.

Auliscus incertus Schmidt.

(Figure 97.)

Auliscus incertus Schmidt, 1886, pl. 89, fig. 18, 19. Rattray, 1888, p. 883 (p. 23). Hustedt, 1928, p. 522, fig. 296.

Geologic range. Late Miocene.

Ecology. According to Hustedt (1928, p. 522) the species is found "Rezent nur von den Balearen bekannt (Weissflog), bedarf der Nachprufung."

Remarks. Valve elliptical with major axis about 1¼ times the minor axis. Transverse median area indistinct rising from central area to the processes. Markings are distinct striae, converging to the processes while the others are diverging. Others are straight along the minor axis, and still others convex towards the processes.

Figure 82. *Asteromphalus darwinii* Ehrenberg. Hypotype no. 3734 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.0500 mm.

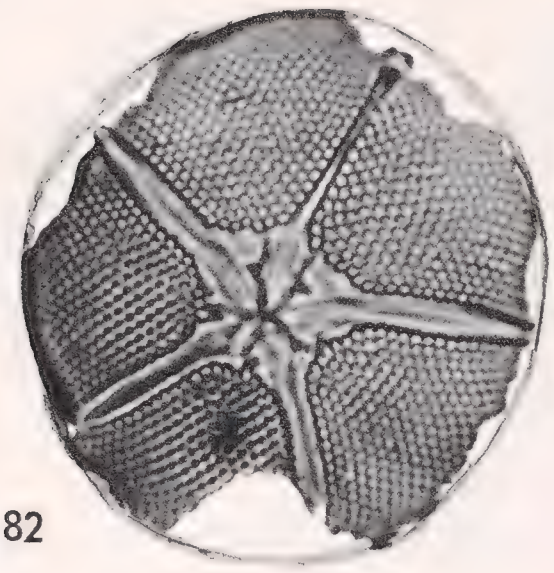
Figure 83. *Aulacodiscus concentricus* (Mann) Boyer. Hypotype no. 3735 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.0705 mm.

Figure 84. *Aulacodiscus brownei* Norman. Hypotype no. 3736 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.1035 mm.

Figure 85. *Aulacodiscus simplex* Rattray. Hypotype no. 3737 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.1220 mm.

Figure 86. *Auliscus albidus* Brun. Hypotype no. 3738 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.1154 mm.

Figure 87. *Auliscus caelatus* Bailey. Hypotype no. 3739 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.0580 mm.



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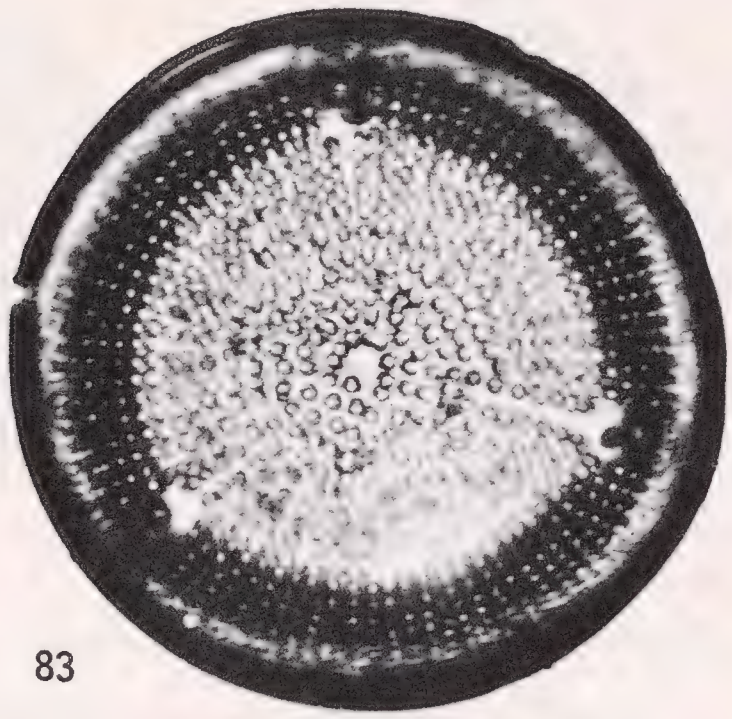

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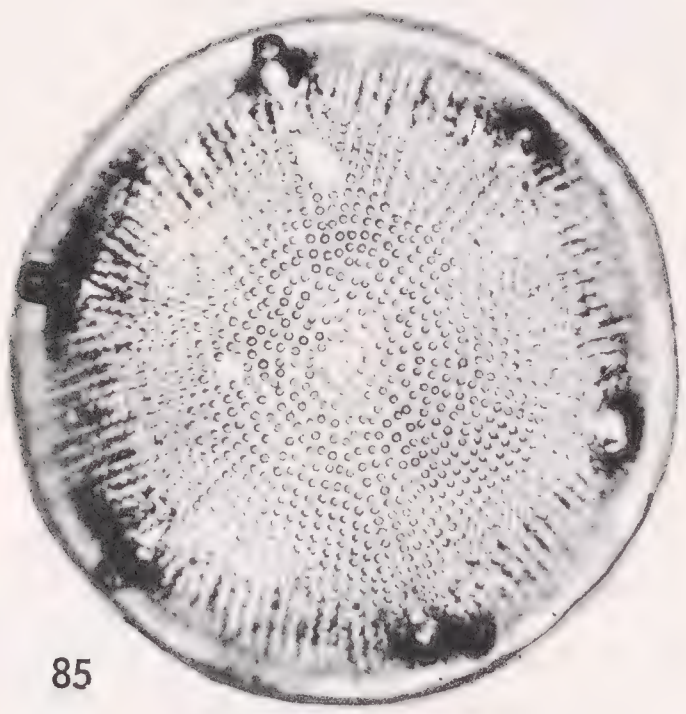

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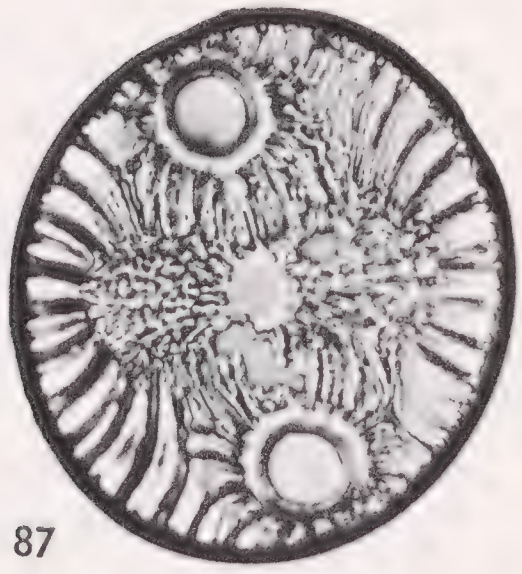

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Auliscus mirablis Grunow.

(Figures 96, 98, 99.)

Auliscus mirablis Grunow, 1863, p. 47, pl. 2, fig. 11. Schmidt, 1886, pl. 89, figs. 10-13. Rattray, 1888, p. 889.

Geologic range. Late Miocene.

Auliscus pruinosus Bailey.

(Figure 101.)

Auliscus pruinosis Bailey, 1854, p. 5, pl. 1, figs. 5-8. Rattray, 1888, p. 882 (p. 22). Hustedt, 1928, p. 511, fig. 286.

Geologic range. Late Miocene.

Ecology. Following Hustedt (1928, p. 521), "Nach Oestrup soll die Art im Holbaekfjord (Danemark) vorkommen. Sonst ist die im Küstengebiet Mittelamerikas häufige Form in den europäischen Meeren meines Wissens noch nicht beobachtet."

Auliscus punctatus Bailey.

(Figures 100, 102-108.)

Auliscus punctatus Bailey, 1853, p. 5, pl. 1, fig. 9. Greville, 1863, p. 49, pl. 3, fig. 15. Rattray, 1888, p. 869. Boyer, 1926, p. 91. Hustedt, *in* Schmidt, 1944, pl. 455, figs. 9-12.

Geologic range. Late Miocene to Recent.

Figure 88. *Auliscus caelatus* var. *constricta* Rattray. Hypotype no. 3740 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.0830 mm.

Figure 89. *Auliscus caelatus* var. *constricta* Rattray. Hypotype no. 3741 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.0868 mm.

Figure 90. *Auliscus caelatus* var. *constricta* Rattray. Hypotype no. 3743 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.0600 mm.

Figure 91. *Auliscus caelatus* var. *constricta* Rattray. Hypotype no. 3744 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.0800 mm.

Figure 92. *Auliscus grunowi* var. *californica* Grunow. Hypotype no. 3745 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.0585 mm.

Figure 93. *Auliscus grunowi* var. *californica* Grunow. Hypotype no. 3746 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.0658 mm.

Figure 94. *Auliscus grunowi* var. *californica* Grunow. Hypotype no. 3747 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.0670 mm.

Figure 95. *Auliscus caelatus* var. *constricta* Rattray. Hypotype no. 3748 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.0600 mm.

Figure 96. *Auliscus mirabilis* Grunow. Hypotype no. 3749 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.0630 mm.

Figure 97. *Auliscus incertus* Schmidt. Hypotype no. 3750 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.0852 mm.

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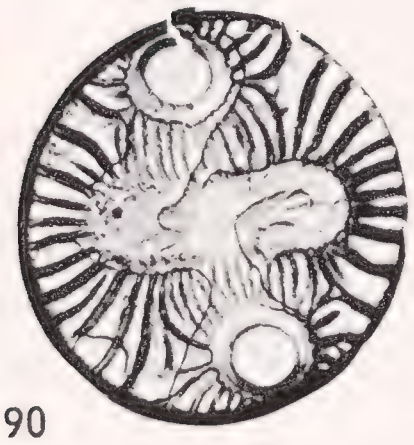
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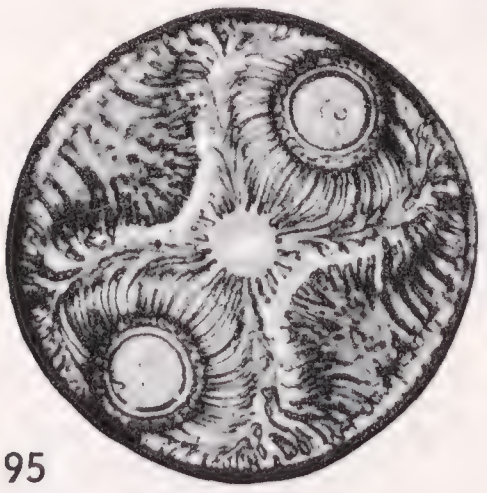
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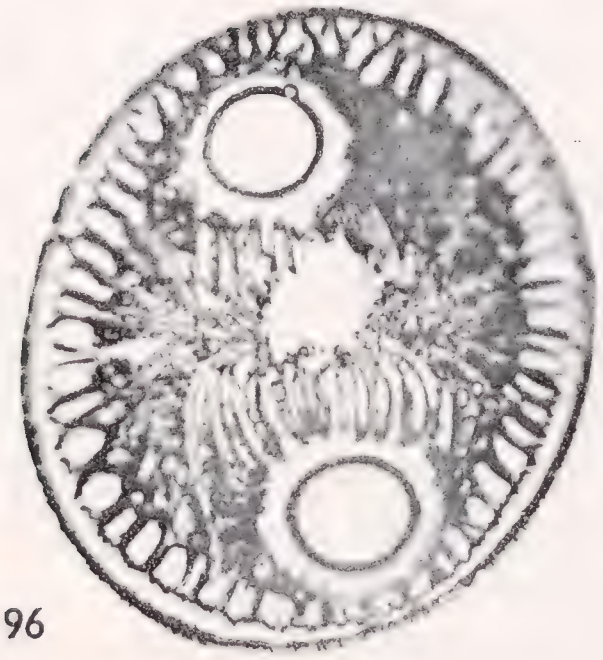
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Remarks. This species is characterized by a closely punctate surface while *A. pruinosis* has a sparsely punctate surface.

Auliscus stockhardtii Janisch.

(Figures 109-112.)

Auliscus stockhardtii Janisch, 1861, p. 163, pl. 1, fig. 4. Schmidt, 1875, pl. 30, figs. 11-13; 1881, pl. 67, fig. 6.

Geologic range. Late Miocene.

Remarks. Valve subcircular with large apiculi near the processes and near the border.

Genus **Glyphodiscus** Greville, 1862

Glyphodiscus stellatus Greville.

(Figure 120a.)

Glyphodiscus stellatus Greville, Trans. Micr. Soc. London, vol. 10, n.s., 1862, p. 91, pl. 9, fig. 5. "Monterey Stone." Schmidt, Atlas, Diat., pl. 80, 1876, fig. 3; pl. 117, 1888, fig. 11. Wolle, Diat. N. Amer. 1894, pl. 76, figs. 8, 9.

Geologic range. Miocene.

Remarks. This is a very characteristic upper Miocene diatom in California.

Figure 98. *Auliscus mirablis* Grunow. Hypotype no. 3751 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.0754 mm.

Figure 99. *Auliscus mirablis* Grunow. Hypotype no. 3752 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.0512 mm.

Figure 100. *Auliscus punctatus* Bailey. Hypotype no. 3753 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.0860 mm.

Figure 101. *Auliscus pruinosus* Bailey. Hypotype no. 3754 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.0677 mm.

Figure 102. *Auliscus punctatus* Bailey. Hypotype no. 3755 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.0830 mm.

Figure 103. *Auliscus punctatus* Bailey. Hypotype no. 3756 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.0948 mm.

Figure 104. *Auliscus punctatus* Bailey. Hypotype no. 3757 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.1110 mm.

Figure 105. *Auliscus punctatus* Bailey. Hypotype no. 3758 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.0844 mm.

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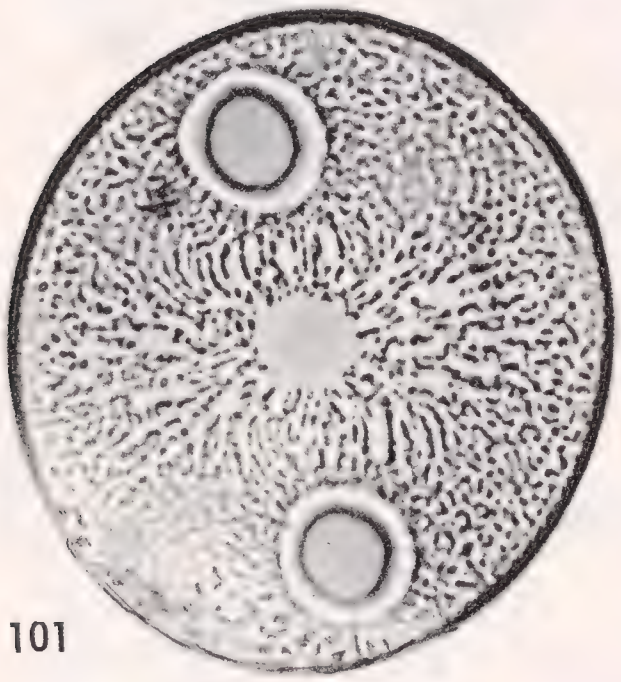

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Suborder Biddulphineae Hustedt, 1930 [14a]
Family Biddulphiaceae Kützing, 1844 [15, 16]
Subfamily Biddulphioideae Schütt, 1896 [16a]

Genus **Biddulphia** Gray, 1831

Biddulphia aurita (Lyngbye) Brébisson and Godey.

(Figure 113.)

Diatoma auritum Lyngbye, 1819, p. 182, pl. 62, fig. D.
Biddulphia aurita (Lyngbye) Brébisson and Godey, 1838, p. 12. Hustedt, 1930, p. 846, fig. 501. Hendey, 1964, p. 103, pl. XXIV, fig. 6.

Geologic range. Late Miocene to Recent.

Ecology. According to Cupp (1943, p. 162), this species is most abundant in the Arctic and boreal seas, and considered it to be a neritic and littoral species.

This species is "usually in long chains attached to a substratum," according to Hendey (1964, p. 103).

Biddulphia aurita var. **obtusa** (Kützing) Hustedt.

(Figure 116.)

Biddulphia obtusa (Kützing) Ralfs, *in* Pritchard, 1861, p. 848, pl. 13, figs. 30-32.
Odontella obtusa Kützing, 1844, p. 137, pl. 18, figs. 8, 1-3, 6-8.
Biddulphia aurita var. *obtusa* (Kützing) Hustedt, 1930, pp. 848-849, fig. 502.
Biddulphia roperiana Greville, 1859, p. 163, pl. 8, figs. 11-13.

Figure 106. *Auliscus punctatus* Bailey. Hypotype no. 3759 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.1120 mm.

Figure 107. *Auliscus punctatus* Bailey. Hypotype no. 3760 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.1110 mm.

Figure 108. *Auliscus punctatus* Bailey. Hypotype no. 3761 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.0966 mm.

Figure 109. *Auliscus stockhardtii* Janisch. Hypotype no. 3762 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.1116 mm.

Figure 110. *Auliscus stockhardtii* Janisch. Hypotype no. 3763 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.1496 mm.

Figure 111. *Auliscus stockhardtii* Janisch. Hypotype no. 3764 (CAS), from locality 1277 (CAS), Monterey, California. Diameter 0.0880 mm.

Figure 112. *Auliscus stockhardtii* Janisch. Hypotype no. 3765 (CAS), from locality 866 (CAS), Monterey, California. Diameter 0.0600 mm.

14a Hustedt, 1930, p. 56.
15 Kützing, 1844, p. 130, as a family Biddulphieae.
16 De-Toni, 1890, p. 910, change in spelling.
16a Schütt, 1896, p. 56.

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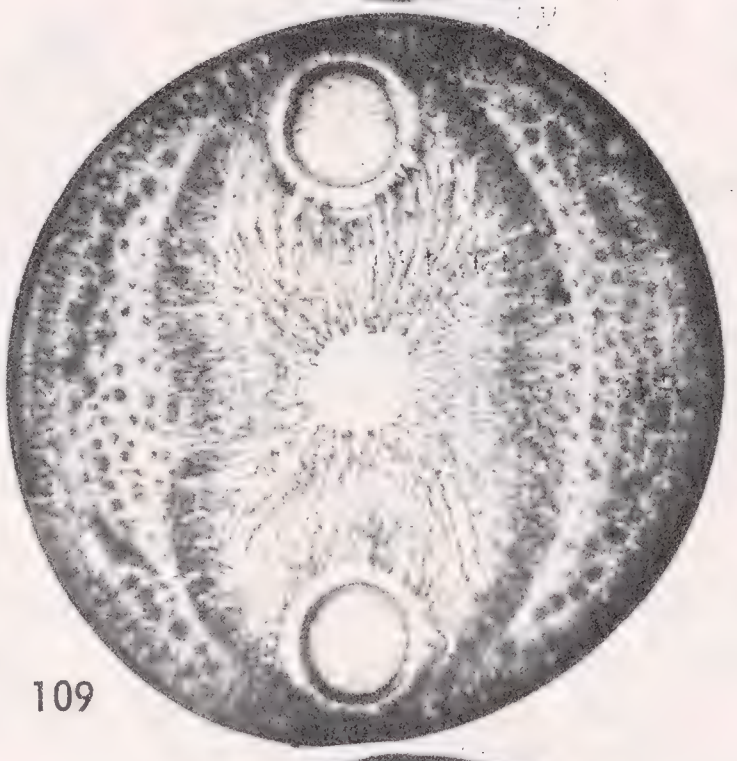

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Geologic range. Late Miocene to Recent.

Ecology. A littoral coast form according to Hustedt (1930, p. 848.)

Remarks. Differs from *B. aurita* in the shortness of the processes, and in the absence of central spines.

Biddulphia rhombus (Ehrenberg) W. Smith

(Figure 118.)

Zygoceros rhombus Ehrenberg, 1839, p. 80, pl. 4, fig. 11 [1840].
Biddulphia rhombus (Ehrenberg) W. Smith, 1856, p. 49, pl. 45, fig. 320; pl. 61, fig. 320. Hustedt, 1930, p. 842, figs. 496, 497.

Geologic range. Late Miocene.

Ecology. This species is a characteristic inhabitant of the littoral zone. It is widely distributed and a neritic species according to Hendey (1964, p. 103).

Biddulphia tuomeyi (Bailey) Roper.

(Figures 117, 119, 120.)

Zygoceros tuomeyii Bailey, 1843, p. 138, pl. 3, figs. 3-9.
Biddulphia tuomeyii (Bailey) Roper, 1859, p. 8, pl. 1, figs. 1,2. Hustedt, 1928, p. 834, fig. 491.

Figure 113. *Biddulphia aurita* (Lyngbye), Brébisson and Godey. Hypotype no. 3766 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0500 mm., breadth 0.0400 mm.

Figure 114. *Triceratium elegans* Greville. Hypotype no. 3767 (CAS), from locality 866 (CAS) Monterey, California. Length 0.0500 mm., breadth 0.0510 mm.

Figure 115. *Triceratium elegans* Greville. Hypotype no. 3768 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0610 mm., breadth 0.0560 mm.

Figure 116. *Biddulphia aurita* var. *obtusa* (Kützing) Hustedt. Hypotype no. 3769 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0355 mm., breadth 0.0260 mm.

Figure 117. *Biddulphia tuomeyi* (Bailey) Roper. Hypotype no. 3770 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0930 mm., breadth 0.0590 mm.

Figure 118. *Biddulphia rhombus* (Ehrenberg) W. Smith. Hypotype no. 3771 (CAS), from locality 866 (CAS), Monterey, California. Length 0.1110 mm., breadth 0.0510 mm.

Figure 119. *Biddulphia tuomeyi* (Bailey) Roper. Hypotype no. 3772 (CAS), from locality 866 (CAS), Monterey, California. Length 0.1600 mm., breadth 0.0690 mm.

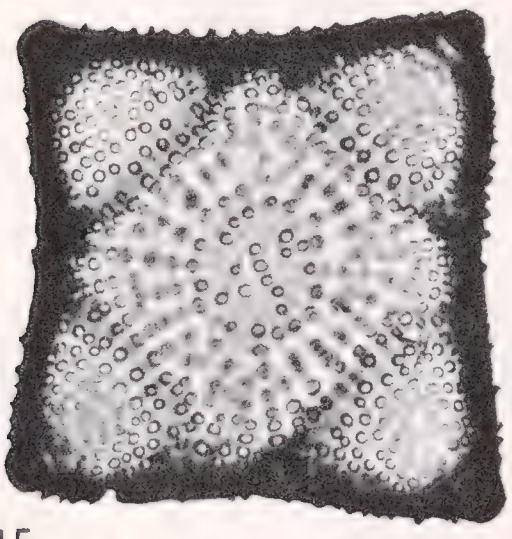
Figure 120. *Biddulphia tuomeyi* (Bailey) Roper. Hypotype no. 3773 (CAS), from locality 866 (CAS), Monterey, California. Length 0.1330 mm., breadth 0.0370 mm.

Figure 120a. *Glyphodiscus stellatus* Greville. Hypotype no. 3120 (CAS), from locality no. 1277 (CAS), Monterey County, California. Diameter 0.0747 mm.

113

114

116



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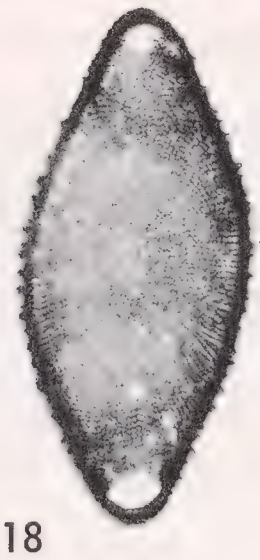

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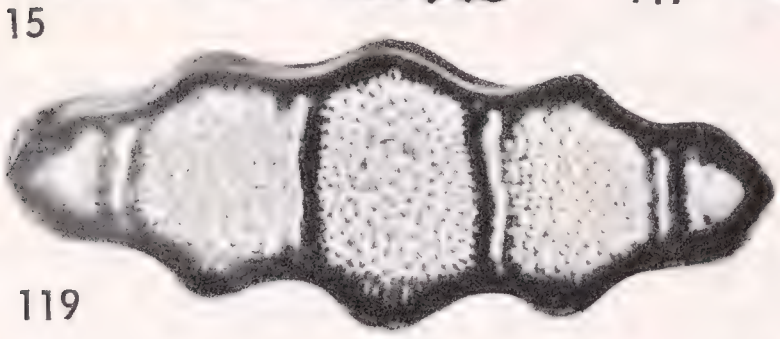

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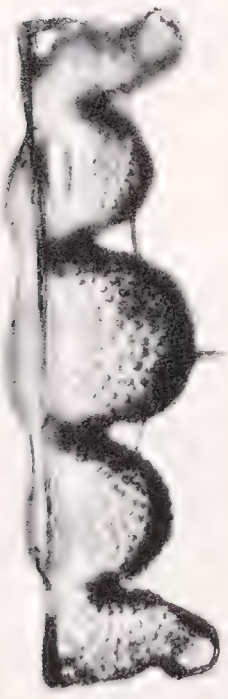

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120a

Biddulphia tuomeyii Bailey, Van Heurck, 1882, pl. 98, figs. 2, 3.
Biddulphia tuomeyii (Bailey), Hanna and Grant, 1926, p. 133, pl. 14, fig. 7.

Geologic range. Late Cretaceous to Recent.

Ecology. "Litoral im Küstengebiet wärmerer Meere weit verbreitet und nicht selten," according to Hustedt (1930, p. 836).

Genus **Trigonium** Cleve, 1868

Trigonium arcticum (Brightwell) Cleve.

(Figure 121.)

Triceratium arcticum Brightwell, 1853, p. 250, pl. 4, fig. 11.
Trigonium arcticum (Brightwell) Cleve, 1886, p. 663. Hendey, 1937, p. 282, pl. 10, fig. 1.

Geologic range. Late Miocene to Recent.

Ecology. According to Hendey (1937, p. 282), this species is "A littoral diatom, not a true member of the plankton and commonly found epiphytic upon larger algae."

Trigonium arcticum var. **californica** (Grunow).

(Figures 123, 126.)

Triceratium arcticum var. *californica* Grunow, *in* Schmidt, 1882, pl. 79, figs. 5, 6.

Geologic range. Late Miocene to Recent.

Remarks. This variety is placed in the genus *Trigonium* following the re-establishment of that genus by Hendey (1937, pp. 280-282).

Figure 121. *Trigonium arcticum* (Brightwell) *Cleve*. Hypotype no. 3123 (CAS), from locality 866 (CAS), Monterey, California. Length 0.1360 mm.

Figure 122. *Triceratium montereyi* Brightwell. Hypotype no. 3775 (CAS), from locality 866 (CAS), Monterey, California. Length 0.1610 mm.

Figure 123. *Trigonium arcticum* var. *californica* (Grunow). Hypotype no. 3776 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0720 mm.

Figure 124. *Triceratium favus* Ehrenberg. Hypotype no. 3777 (CAS), from locality 27295-162 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Length 0.2400 mm.

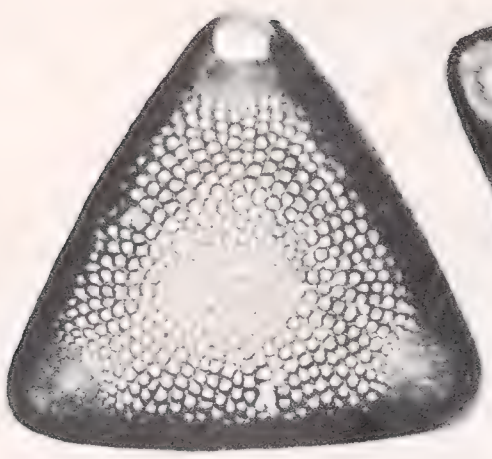
Figure 125. *Triceratium margaritiferum* Cleve. Hypotype no. 3777a (CAS), from locality 1277 (CAS), Monterey, California. Length 0.0540 mm.

Figure 126. *Trigonium arcticum* var. *californica* (Grunow). Hypotype no. 3778 (CAS), from locality 1277 (CAS), Monterey, California. Length 0.0770 mm.

Figure 127. *Triceratium montereyi* Brightwell. Hypotype no. 3779 (CAS), from locality 866 (CAS), Monterey, California. Length 0.3010 mm.

Figure 128. *Triceratium montereyi* Brightwell. Hypotype no. 3779 (CAS), from locality 866 (CAS), Monterey, California. Length 0.3010 mm. Same specimen as figure 127.

Figure 128a. *Triceratium quadrangulare* Greville. Hypotype no. 3781 (CAS), from locality 1278 (CAS), Monterey, California. Length 0.1260 mm.



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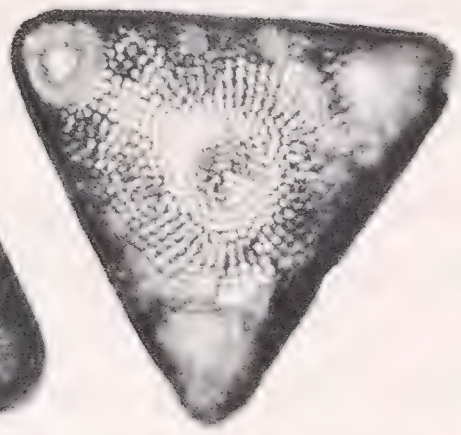

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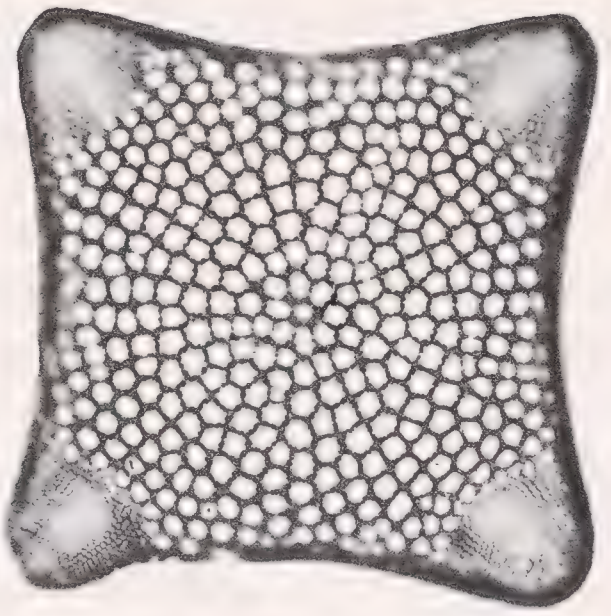

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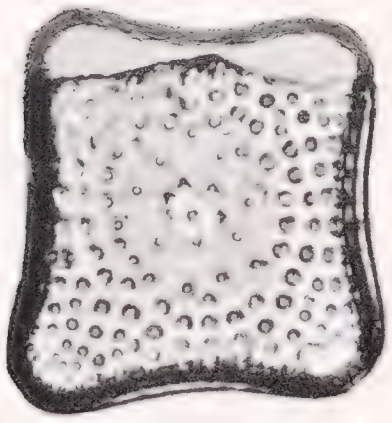

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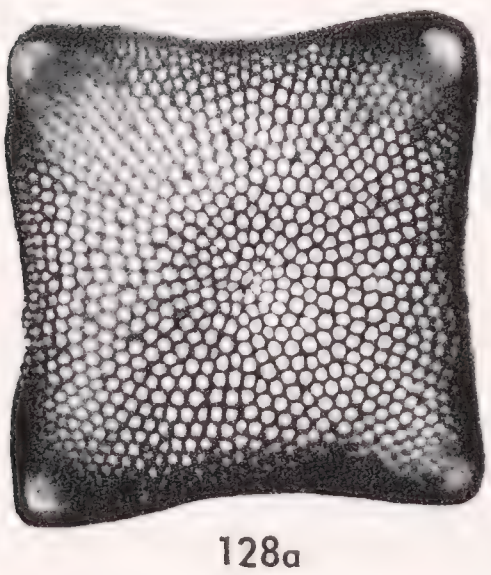

128a

Subfamily Triceratioideae Schütt, 1896 [17, 18]

Genus **Triceratium** Ehrenberg, 1840

The complex structure of the valve is profoundly different from anything observed in the genus *Biddulphia*. "The sides of the cell are usually straight, sometimes very slightly convex. The angles are furnished with a stout cornutate process. The valve surface is covered with a regular hexagonal loculation. The loculi are usually open upon the outer surface, while the lower wall or floor is furnished with poroids. The valve mantle is narrow. The girdle is always dimpled and finely punctate. Small spines are usually present on the valve surface at the point of confluence of the walls of the loculi; there are often developed at the margin of the valve and have the appearance of a palisade," according to Hendey (1937, p. 282).

Triceratium elegans Greville.

(Figures 114, 115.)

Amphitetras elegans Greville, 1866, pp. 8, 9, pl. 2, fig. 24.
Triceratium elegans Greville, *in* Schmidt, 1886, pl. 99, figs. 10-13.
Biddulphia elegans (Greville) Boyer, 1900, p. 717.
"*Tr (Odontella) Grev.* forma major."Grunow, *in* Van Heurck, pl. 109, fig. 1.

Geologic range. Late Miocene.

Triceratium favus Ehrenberg.

(Figure 124.)

Triceratium favus Ehrenberg, 1839, p. 159, pl. 4, fig. 10 [1841]. Hustedt, 1930, p. 798, figs. 462, 463. Hendey, 1937, pp. 283-284, pl. 10, figs. 2, 3.

Geologic range. Late Miocene to Recent.

Ecology. According to Hustedt (1928, p. 801) this species is "litoral in allen europäischen Meeren sehr verbreitet und häufig, oft weit flussaufwarts noch anzutreffen, ebenso in neritischen Plankton fast stets vorhanden."

Triceratium margaritiferum Cleve.

(Figure 125.)

Triceratium margaritiferum Cleve, 1881, p. 26, pl. 6, fig. 76. Schmidt, 1890, pl. 152, fig. 32.
Biddulphia penitens Hanna and Grant, 1926, p. 132, pl. 14, figs. 4, 5.

Geologic range. Late Miocene.

Triceratium montereyi Brightwell.

(Figures 122, 127, 128.)

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17 Schütt, 1896, p. 56, as a subtribe Triceratinea.
18 Hustedt, 1930, p. 56, new status and change of spelling.

Triceratium montereyi BRIGHTWELL, 1853, p. 251, pl. 4, fig. 18. MÖLLER, 1882, p. 143, pl. 22, figs. 9-11. WOLLE, 1894, pl. 102, fig. 2; pl. 107, figs. 6, 9.

GEOLOGIC RANGE. Late Miocene to Recent.

Triceratium quadrangulare Greville.

(Figure 128a.)

Triceratium quadrangulare GREVILLE, 1865, p. 10, pl. 2, fig. 26. SCHMIDT, 1885, pl. 81, fig. 3. WOLLE, 1894, pl. 106, fig. 8.

GEOLOGIC RANGE. Late Miocene.

Triceratium thumii Schmidt.

(Figure 129.)

Triceratium thumii SCHMIDT, 1886, pl. 93, fig. 2; 1888, pl. 126, fig. 1. PANTOCSEK, 1886, pl. 5, fig. 39.

GEOLOGIC RANGE. Late Miocene to Recent.

Genus **Lithodesmium** Ehrenberg, 1840

Lithodesmium californicum Grunow.

(Figure 130.)

Lithodesmium californicum GRUNOW, *in* Van Heurck, 1883, pl. 115, fig. 9. SCHMIDT, 1890, pl. 158, fig. 11.

GEOLOGIC RANGE. Late Miocene to early Pliocene.

Lithodesmium cornigerum Brun.

(Figure 131.)

Lithodesmium cornigerum BRUN, 1896, p. 239, pl. 24, figs. 15-17. HANNA, 1930, p. 189, pl. 14, figs. 9, 10.

GEOLOGIC RANGE. Early Pliocene to late Pliocene.

REMARKS. This diatom is shaped like a three-bladed propeller and it is probably one of the most distinctive diatoms from California fossil deposits. It seems to be an excellent indicator of Pliocene age inasmuch as it has been found in Pliocene rocks on the only four other occasions when found. It has not been found in the Monterey shale at its type area or at any other place.

Lithodesmium minusculum Grunow.

(Figure 132.)

Lithodesmium minusculum GRUNOW, *in* Van Heurck, 1883, pl. 16, figs. 1-5.
Lithodesmium minusculum forma *major* GRUNOW, *in* Van Heurck, 1883, pl. 116, fig. 6.

GEOLOGIC RANGE. Late Miocene to early Pliocene.

Subfamily Isthmoideae Schütt, 1896 [19, 20]

Genus **Isthmia** Agardh, 1832

Isthmia nervosa Kützing.

Isthmia nervosa Kützing, 1844, p. 137, pl. 19, fig. 5. Cupp, 1943, p. 166, fig. 116. Hendey, 1964, p. 110, pl. XXV, fig. 3.

Geologic range. Late Miocene to Recent.

Ecology. This is an epiphytic littoral species. It occurs in the "plankton as tychopelagic species; widespread, but never abundant. Usually found in colder waters," according to Cupp (1943, p. 167).

Family Anaulaceae Schütt, 1896 [21, 22]

Subfamily Anauloideae Heiden-Kolbe, 1928 [22a]

Genus **Porpeia** Bailey, 1961

Porpeia quadriceps Bailey.

(Figure 133.)

Porpeia quadriceps Bailey, Ralfs *in* Pritchard, 1861, p. 850, pl. 6, fig. 6. Mann, 1907, p. 315. Hanna and Grant, 1926, p. 164, pl. 20, figs. 6, 7.

Porpeia quadriceps Bailey var. *intermedia* Grunow, *in* Van Heurck, 1882, pl. 95 bis, figs. 13, 14.

Geologic range. Late Miocene.

Genus **Anaulus** Ehrenberg, 1844

Analus mediterraneus var. **intermedia** Grunow.

(Figure 134.)

Analus mediterraneus var. *intermedia* Grunow, *in* Van Heurck, 1882, pl. 102, fig. 9. Hustedt, 1930, p. 893, fig. 535.

Geologic range. Late Miocene.

Ecology. Inhabits littoral coasts of warm seas, according to Hustedt, (1930, p. 893).

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19 Schütt, 1896, p. 56, as a tribe Isthmiinae.

20 Hustedt, 1930, p. 56, new status and change of spelling.

21 Schütt, 1896, p. 56, as a tribe Anauleae.

22 Hustedt, 1930, p. 56, new status and change of spelling.

22a Heiden-Kolbe, 1928, p. 464.

Family CHAETOCERACEAE H. L. Smith, 1872 [23, 24]

Subfamily CHAETOCEROIDEAE Kolbe, 1927[25]

Genus **Chaetoceros** Ehrenberg, 1844

Chaetoceros cinctus Gran.

(Figure 135.)

Chaetoceros cinctus GRAN, 1897, p. 24, pl. 2, figs. 23-27.
Chaetoceros incurvus BAILEY, 1854, p. 9, figs. 30-32.

GEOLOGIC RANGE. Early Pliocene to Recent.

ECOLOGY. According to Cupp (1943, p. 142) this is a neritic and south temperate species.

Chaetoceros subsecundus (Grunow) Hustedt.

(Figure 136.)

Syndendrium diadema EHRENBERG, 1854, pl. 35A, group 18, fig. 13.
Chaetoceros subsecundus (Grunow) HUSTEDT, 1930, p. 709, fig. 404.

GEOLOGIC RANGE. Early Pliocene to Recent.

ECOLOGY. According to Hustedt (1930, p. 710), this species is "Neritisch an den Küsten Europas bis ins Nördliche Eismer, auch im Mittelmeer von Pavillard und Forti beobachtet."

Genus **Periptera** Ehrenberg, 1845

Periptera species.

(Figures 137, 138.)

GEOLOGIC RANGE. Early Pliocene to middle Pliocene.

REMARKS. The central elevated area of the ovate valve bears about two to five thick but sharp spines. Long, sharp spines are also present along the narrow border.

This differs from the commonly known *Periptera tetracladia* in which the narrower central area lacks spines.

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23 H. L. Smith, 1872, p. 14, as a family Chaetocereae.

24 De-Toni, 1890, p. 920, change of spelling.

25 Kolbe, 1927, p. 31.

Figure 129. *Triceratium thumii* Schmidt. Hypotype no. 3782 (CAS), from locality 1277 (CAS), Monterey, California. Length 0.2253 mm.

Figure 130. *Lithodesmium californicum* Brun. Hypotype no. 3783 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0520 mm.

Figure 131. *Lithodesmium cornigerum* Brun. Hypotype no. 3784 (CAS), from locality 27295-29 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Length 0.0617 mm.

Figure 132. *Lithodesmium minusculum* Grunow. Hypotype no. 3785 (CAS), from locality 27295-7 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Length 0.0362 mm.

Figure 133. *Porpeia quadriceps* Bailey. Hypotype no. 3786 (CAS), from locality 866 (CAS), Monterey, California. Length 0.1290 mm., breadth 0.0385 mm.

Figure 134. *Anaulus mediterraneus* var. *intermedia* Grunow. Hypotype no. 3787 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0543 mm., breadth 0.0190 mm.

Figure 135. *Chaetoceros cintus* Gran. Hypotype no. 3788 (CAS), from locality 27295-7 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Length 0.0261 mm.

Figure 136. *Chaetoceros subsecundus* (Grunow) Hustedt. Hypotype no. 3789 (CAS), from locality 27295-3 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Length 0.0330 mm.

Figures 137, 138. *Periptera* new species. Hypotypes nos. 3790, 3791 (CAS), from locality 27295-122 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Length 0.0262 mm.

Figure 139. *Xanthiopyxis diaphana* Forti. Hypotype no. 3792 (CAS), from locality 27295-3 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Length 0.0445 mm., breadth 0.0329 mm.

Figure 140. *Xanthiopyxis diaphana* Forti. Hypotype no. 3793 (CAS), from locality 27295-3 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Length 0.0438 mm., breadth 0.0229 mm.

Figures 141, 142. *Xanthiopyxis diaphana* Forti. Hypotype no. 3794 (CAS) from locality 27295-3 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Length 0.0326 mm., breadth 0.0208 mm.

Figure 143. *Xanthiopyxis diaphana* Forti. Hypotype no. 3795 (CAS), from locality 27295-3 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Length 0.0500 mm., breadth 0.0220 mm.

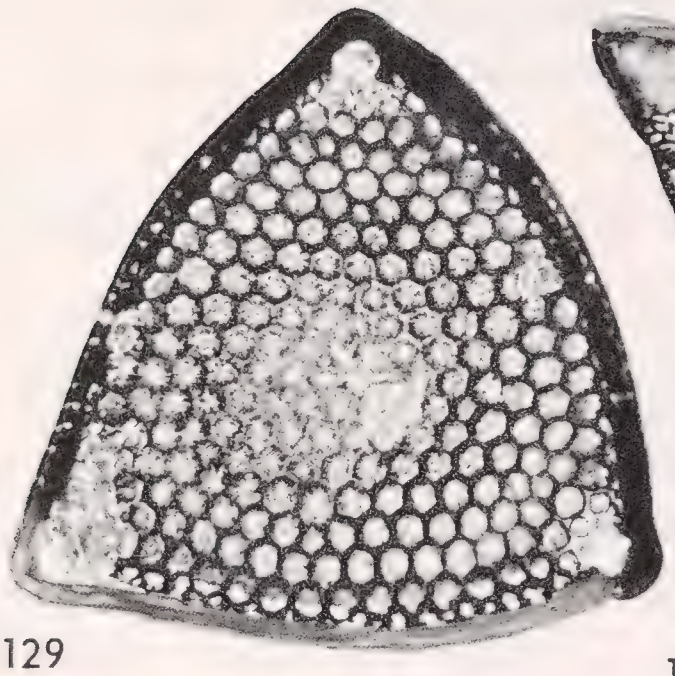
Figure 144. *Xanthiopyxis lacera* Forti. Hypotype no. 3796 (CAS), from locality 27295-7 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Length 0.0700 mm., breadth 0.0479 mm.

Figure 145. *Xanthiopysis lacera* Forti. Hypotype no. 3797 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0500 mm.

Figure 146. *Xanthiopyxis oblonga* Ehrenberg. Hypotype no. 3798 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0370 mm., breadth 0.0170 mm.

Figures. 147, 148. *Xanthiopyxis oblonga* Ehrenberg. Hypotypes nos. 3799, 3800 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0390 mm., breadth 0.0150 mm.

Figure 149. *Xanthiopyxis oblonga* Ehrenberg. Hypotype no. 3801 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0230 mm.



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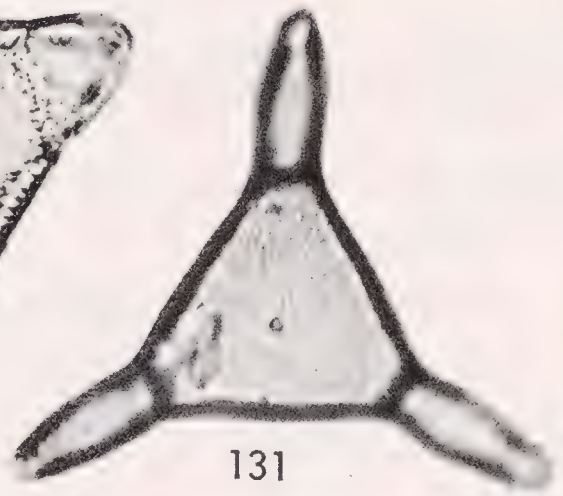

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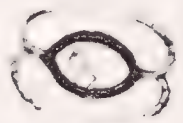

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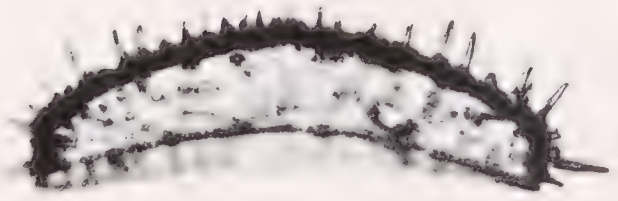

149

Genus **Xanthiopyxis** Ehrenberg, 1845

Xanthiopyxis cingulata Ehrenberg.

Xanthiopyxis cingulata Ehrenberg, 1854, pl. 33, group 17, fig. 18. Hanna and Grant, 1926, pl. 21, no. 9 .

Geologic range. Late Miocene to late Pliocene.

Remarks. Valves circular with spines uniformly distributed over the surface and projecting outwardly from the border.

Xanthiopyxis diaphana Forti.

(Figures 139-143.)

Xanthiopyxis diaphana Forti, 1913, p. 1554, pl. 2, figs. 13, 19, 26.

Geologic range. Early Pliocene to middle Pliocene.

Remarks. This species is characterized by convex, hyaline, and ovate valves. The border is narrow and is entirely devoid of spines or beads.

Xanthopyxis lacera Forti.

(Figures 144, 145.)

Xanthiopyxis lacera Forti, 1913, p. 1555, pl. 2, figs. 14-18.

Geologic range. Late Miocene to early Pliocene.

Xanthiopyxis oblonga Ehrenberg.

(Figures 146-149.)

Xanthiopyxis oblonga Ehrenberg, 1854, pl. 33, gr. 17, fig. 17. Forti, 1913, p. 1554, pl. 2, fig. 38.

Geologic range. Late Eocene to Recent.

Xanthiopyxis ovalis Lohman.

(Figures 150-152.)

Xanthiopyxis ovalis Lohman, 1938, p. 91, pl. 20, fig. 6; pl. 22, fig. 12.

Geologic range. Pliocene.

Remarks. This species is characterized by a distinct oval-shaped valve, and by spines never projecting beyond the margin of the valve. According to Lohman (1938, p. 91) this species is confined to the Pliocene.

Xanthiopyxis umbonata (Greville).

(Figure 153.)

"Xanthiopyxis ? umbonatus n. sp., Grev.", 1886, p. 2, pl. 1, fig. 5.
Xanthiopyxis ? umbonata Greville, 1894, p. 1156.

GEOLOGIC RANGE. Late Miocene.

REMARKS. This species was originally described from the "Monterey deposit" by Greville.

Xanthiopyxis sp. A.

(Figures 154, 154a.)

GEOLOGIC RANGE. Early Pliocene to middle Pliocene.

REMARKS. Valves are ovate, convex, with the central hyaline area having a central blunt protuberance. Short, sharp spines surround the central zone in a somewhat radial pattern, decrease toward the border and do not project beyond the border.

Xanthiopyxis sp. B.

(Figure 156.)

GEOLOGIC RANGE. Early Pliocene to middle Pliocene.

REMARKS. Valves are ovate, convex, with a hyaline center area marked with a few irregularly arranged beads. The narrow border is marked with a single row of beads.

Xanthiopyxis sp. C.

(Figures 157, 158.)

GEOLOGIC RANGE. Early Pliocene.

REMARKS. Valves convex, hyaline and ovate. The border is characterized by a row of beads.

Xanthiopyxis sp. D.

(Figures 155, 155a.)

GEOLOGIC RANGE. Miocene to Pliocene.

REMARKS. This dome-shaped species with dense spines is common in collections of the above stated geologic range.

Family RUTILARIACEAE Pantocsek, 1889[26, 27]

Subfamily RUTILARIODEAE Boyer, 1916[28]

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26 Pantocsek, 1889, p. 74, as a family Rutilariae.

27 De-Toni, 1894, p. 1020, change of spelling.

28 Boyer, 1916, p. 13.

Genus **Rutilaria** Greville, 1863

Rutilaria epsilon (Kitton) Greville.

(Figure 159.)

Nitzschia epsilon Kitton, 1863, p. 228 as synonym.
Rutilaria epsilon (Kitton) Greville, 1863, p. 228, pl. 9, fig. 1. Hanna, 1928, pl. 8, fig. 3.

Geologic range. Late Miocene.

Suborder Rhizosoleniineae Hendey, 1964 [29]
Family Bacteriastraceae Lebour, 1930 [30, 31]
Subfamily Bacteriastroideae Hendey, 1937 [32]

Genus **Bacteriastrum** Shadbolt, 1854

Bacteriastrum delicatulum Cleve.

Bacteriastrum delicatulum Cleve, 1897, p. 298, fig. 15. Schmidt, 1920, pl. 328, fig. 609.

Geologic range. Early Pliocene to Recent.

Ecology. According to Hendey (1964, p. 139), this is "An oceanic form, common in temperate waters."

Bacteriastrum varians Lauder.

Bacteriastrum varians Lauder, 1863, p. 8, pl. 3, figs. 1-6. Hendey, 1937, p. 308.

Geologic range. Early Pliocene to Recent.

Ecology. This oceanic species is found commonly in tropical waters, according to Hendey (1937, p. 308).

Suborder Fragilariineae Hendey, 1964 [33]
Family Fragilariaceae Kützing, 1844 [34, 35]
Subfamily Fragilarioideae Schütt, 1896 [36]

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29 Hendey, 1964, p. 57.
30 Lebour, 1930, p. 23, as a family Bacteriastraceae.
31 Hendey, 1937, p. 204, new status and change of spelling.
32 Hendey, 1937, p. 204
33 Hendey, 1964, p. 57
34 Kützing, 1844, pp. 32, 42, as a family Fragilarieae.
35 De-Toni, 1890, p. 893, new status and change of spelling.
36 Schütt, 1896, p. 117.

Genus **Glyphodesmis** Greville, 1862

Glyphodesmis sigmoideus Hanna and Grant.

Glyphodesmis sigmoideus HANNA AND GRANT, 1926, p. 145, pl. 16, fig. 10.

GEOLOGIC RANGE. Late Miocene.

Glyphodesmis williamsonii (W. Smith) Grunow.

(Figure 160.)

Himantididium ? williamsonii, W. SMITH, 1856, p. 14, pl. 33, fig. 287.
Glyphodesmis williamsonii (W. Smith). GRUNOW, 1880, pl. 36, fig. 14; HUSTEDT, 1931, p. 124, figs. 646 a-c.

GEOLOGIC RANGE. Late Miocene.

ECOLOGY. According to Hustedt (1931, p. 125) this species is "Im Litoral der europäischen Küsten überall verbreitet, aber nur im Mittelmeergebiet häufiger vorkommend."

Genus **Opephora** Petit, 1880

Opephora schwartzii (Grunow) Petit.

(Figures 161-165.)

Fragilaria schwartzii GRUNOW, 1863, p. 143.
Opephora schwartzii (Grunow) PETIT, *in* Pelletan, 1889, p. 88; BOYER, 1916, pl. 10, figs. 16, 19.

GEOLOGIC RANGE. Late Miocene to Recent.

ECOLOGY. According to Hendey (1964, p. 159), this species is a "Marine littoral, not common, but occurring on the west coasts of the British Isles."

Genus **Plagiogramma** Greville, 1859

Plagiogramma antillarum Cleve.

(Figures 166, 167.)

Plagiogramma antillarum CLEVE, 1878, p. 10, pl. 3, fig. 16; MANN, 1925, p. 129, pl. 29, fig. 1.

GEOLOGIC RANGE. Late Miocene.

ECOLOGY. Found living in chains.

Plagiogramma attenuatum Cleve.

(Figure 168.)

Plagiogramma attenuatum CLEVE, 1878, p. 10, pl. 3, fig. 18; MANN, 1925, p. 129, pl. 29, fig. 2.

GEOLOGIC RANGE. Late Miocene.

Figures 150, 151. *Xanthiopyxis ovalis* Lohman. Hypotypes nos. 3802, 3803 (CAS), from locality 27295-122 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Length 0.0336 mm.

Figure 152. *Xanthiopyxis ovalis* Lohman. Hypotype no. 3804 (CAS), from locality 27295-7 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Length 0.0257 mm.

Figure 153. *Xanthiopyxis umbonata* (Greville). Hypotype no. 3805 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0421 mm.

Figure 154. *Xanthiopyxis* new species A. Hypotype no. 3806 (CAS), from locality 27295-7 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Length 0.0378 mm.

Figure 154a. *Xanthiopyxis* new species A. Hypotype no. 3807 (CAS), from locality 27295-7 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Length 0.0426 mm.

Figures 155, 155a. *Xanthiopyxis* new species D. Hypotypes nos. 3808, 3809 (CAS), from locality 27295-7 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Length 0.0400 mm.

Figure 156. *Xanthiopyxis* new species B. Hypotype no. 3810 (CAS), from locality 27295-7 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Length 0.0230 mm., breadth 0.0100 mm.

Figure 157. *Xanthiopyxis* new species C. Hypotype no. 3811 (CAS), from locality 27295-7 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Length 0.0272 mm., breadth 0.0083 mm.

Figure 158. *Xanthiopyxis* new species C. Hypotype no. 3812 (CAS), from locality 27295-7 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Length 0.0162 mm., breadth 0.0032 mm.

Figure 159. *Rutilaria epsilon* (Kitton) Greville. Hypotype no. 3095 (CAS), from locality 866 (CAS), Monterey, California. Length 0.1516 mm., breadth 0.0250 mm.

Figure 160. *Glyphodesmis williamsonii* (W. Smith) Grunow. Hypotype no. 3813 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0860 mm.

Figure 161. *Opephora schwartzii* (Grunow) Petit. Hypotype no. 3814 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0610 mm., breadth 0.0140 mm.

Figure 162. *Opephora schwartzii* (Grunow) Petit. Hypotype no. 3815 (CAS), from locality 27295-7 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Length 0.0282 mm.

Figure 163. *Opephora schwartzii* (Grunow) Petit. Hypotype no. 3816 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0310 mm.

Figure 164. *Opephora schwartzii* (Grunow) Petit. Hypotype no. 3817 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0432 mm.

Figure 165. *Opephora schwartzii* (Grunow) Petit. Hypotype no. 3818 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0452 mm.

Figures 166, 167. *Plagiogramma antillarum* Cleve. Hypotypes nos. 3819, 3820 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0910 mm., breadth 0.0170 mm.

Figure 168. *Plagiogramma attenuatum* Cleve. Hypotype no. 3821 (CAS), from locality 866 (CAS), Monterey, California. Length 0.1800 mm.

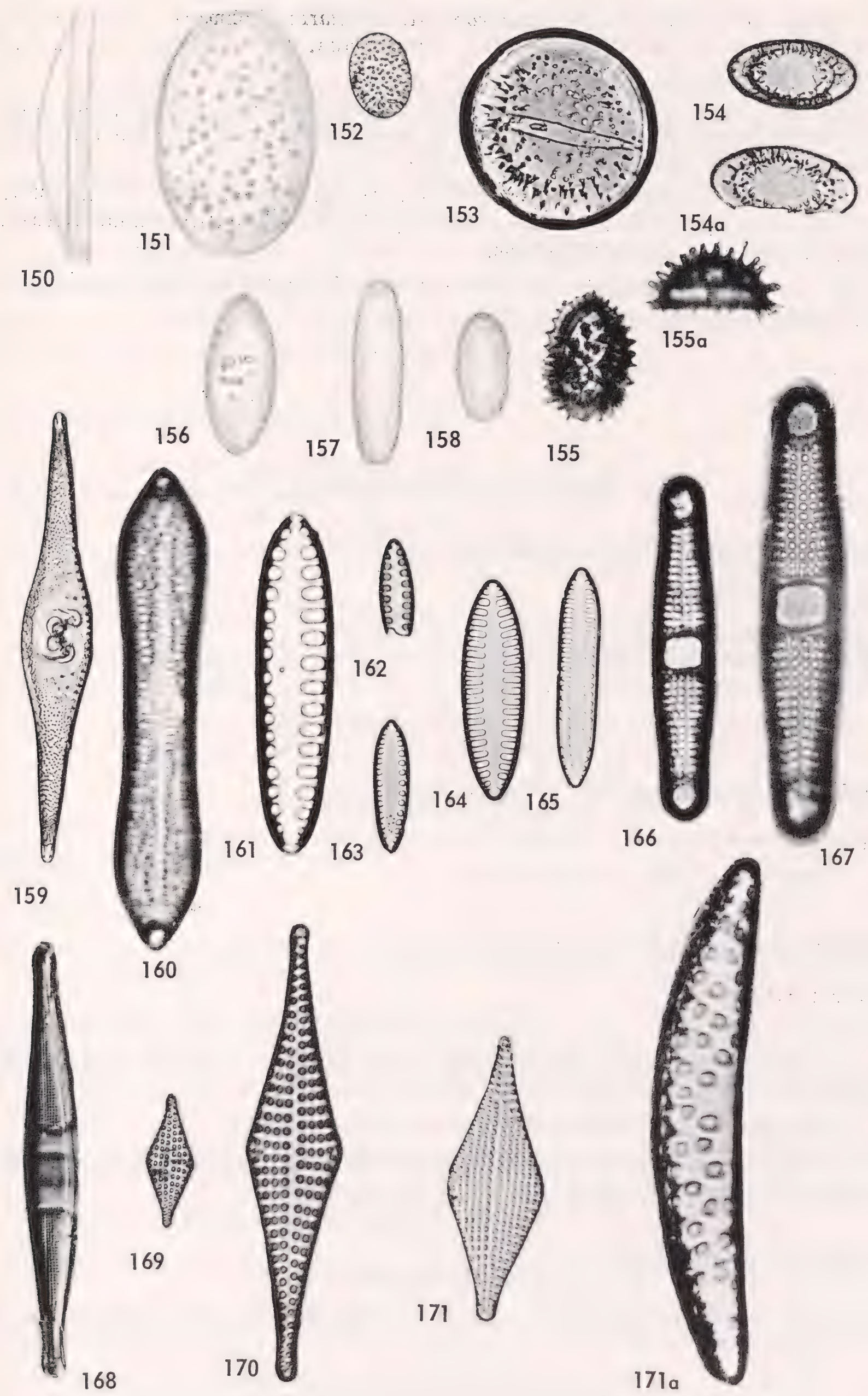
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FIGURE 169. *Rhaponeis amphiceros* var. *angularis* (Lohman). Hypotype no. 3822 (CAS), from locality 27295-7 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Length 0.0383 mm.

FIGURE 170. *Rhaphoneis amphiceros* var. *angularis* (Lohman). Hypotype no. 3823 (CAS), from locality 27295-7 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Length 0.0750 mm.

FIGURE 171. *Rhaphoneis elegans* Pantocsek and Grunow. Hypotype no. 3824 (CAS), from locality 27295-122 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Length 0.0336 mm.

FIGURE 171A. *Leudugeria janischii* (Grunow). Hypotype no. 3824a (CAS), from locality 866 (CAS), Monterey, California.

Genus **Rhaphoneis** Ehrenberg, 1845

Rhaphoneis amphiceros var. **angularis** (Lohman).

(Figures 169, 170.)

Rhaphoneis angularis LOHMAN, 1938, pl. 22, figs. 6-8.
Rhaphoneis amphiceros Ehrenberg, PERAGALLO, 1901, pl. 83, fig. 19.
Rhaphoneis rhombus Ehrenberg, HANNA, 1951, p. 283, fig. 2 (6).

GEOLOGIC RANGE. Early Pliocene to late Pliocene.

Rhaphoneis amphiceros var. **elongata** Peragallo.

Rhaphoneis amphiceros var. *elongata* PERAGALLO, 1901, pl. 33, fig. 10.

GEOLOGIC RANGE. Early Pliocene.

Rhaphoneis elegans Pantocsek and Grunow.

(Figure 171.)

Rhaphoneis gemmifera var. *elegans* PANTOCSEK AND GRUNOW, *in* Pantocsek, 1886, p. 34, pl. 2, fig. 21; pl. 20, fig. 179; pl. 27, fig. 264; pl. 30, fig. 317.
Rhaphoneis elegans Pantocsek and Grunow, HANNA, 1932, p. 213, pl. 15, figs. 5-7.

GEOLOGIC RANGE. Middle Miocene to early Pliocene.

REMARKS. This species is distinguished by the straight rows of punctae and the expanded central portion of the valve.

Rhaphoneis parlis Hanna.

Rhaphoneis parlis HANNA, 1932, p. 214, pl. 16, figs. 2-4. LOHMAN, 1948, p. 182, pl. 11, fig. 10.

GEOLOGIC RANGE. Early Miocene to middle Pliocene.

Genus **Thalassionema** Hustedt, 1932

According to Hendey (1964, p. 165), " The genus *Thalassionema* has often been attributed to Grunow because of the explanatory note made by him upon pl. 43 of Van Heurck's Synopsis (1880-85) under *Thalassiothrix nitzschioides* Grun. which was as follows: - 'On pourrait peut-être en créer un nouveau genre nommé *Thalassionema*.

"Owing to the fact that Grunow did not definitely accept this as a new genus, his publication of this name must be ruled as invalid. The authority is attributed to Hustedt who gave a full generic description followed by a description of *Thalassionema nitzschioides*."

Thalassionema nitzschioides (Grunow).

Synedra nitzschioides Grunow, 1862, p. 403.
Thalassionema nitzschioides (Grunow) Peragallo, 1901, p. 320, pl. 83, figs. 17, 18; Hustedt, 1932, p. 244, fig. 725.
"Thalassiothrix ?? nitzschioides Grun (Synedra Grun 1.c)", *in* Van Heurck, 1881, pl. 43, figs. 7-10.

Geologic range. Early Pliocene to Recent.

Ecology. This is a neritic and north temperate species, according to Cupp (1943, p. 183).

Subfamily Tabellarioideae Kützing, 1844 [37, 38]

Genus **Rhabdonema** Kützing, 1844

Rhabdonema biquadratum Brun.

(Figures 172-175.)

Rhabdonema biquadratum Brun, 1889, p. 52, pl. 1, fig. 5. Schmidt, 1899, pl. 218, figs. 2-6. Hanna, 1928, pl. 8, fig. 1.

Geologic range. Late Miocene.

Rhabdonema japonicum var. **sparsicostatum** Tempère and Brun.

(Figure 176.)

Rhabdonema japonicum var. *sparsicostatum* Tempère and Brun, 1889, p. 53. Schmidt, 1899, pl. 218, figs. 13-18.

Geologic range. Late Miocene.

Genus **Leudugeria** Tempère, 1893

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37 Kützing, 1844, pp. 119, 126, as a family Tabellariceae.
38 Karsten, 1905, p. 396, new status and change of spelling.

Leudugeria janischii (Grunow).

(Figure 171a.)

Epithema ? sp. Leuduger Fortmorel, Cat. Diat. Ceylon, 1879, p. 23, pl. 9, fig. 87.
Leudugeria janischii Grunow, *in* Van Heurck, Treat. Diat. 1896, p. 539, fig. 287.
Euodia janischii Grunow, *in* Van Heurck, Diat. Belgique, 1883, pl. 127, figs. 1-4.
Leudugeria epithemoides Tempère, Le Diatomiste, vol. 2, p. 17, 1893.

Geologic range. This species was first discovered living in the western Pacific and southward, but it is also found frequently in the upper Miocene of California.

Genus **Entopya** Ehrenberg, 1848

Entopya australis var. **gigantea** (Greville).

(Figures 177-180.)

Gephyra gigantea Greville, 1866, p. 122, pl. 11, figs. 7, 8.
Entopya australis var. *gigantea* (Greville), Fricke, *in* Schmidt, 1902, pl. 230, figs. 1-11.

Geologic range. Late Miocene.

Suborder Achnanthineae Hendey, 1964 [39]

Subfamily Cocconeioideae Kützing, 1844 [40, 41]

Genus **Cocconeis** Ehrenberg, 1838

Cocconeis decipiens Cleve.

(Figure 181.)

Cocconeis decipiens Cleve, 1873, p. 14, pl. 1, fig. 6. Hustedt, 1933, pp. 353-354, fig. 808.
Cocconeis sigma Pantocsek, 1886, p. 32, pl. 8, fig. 68.
Cocconeis dirupta var. *sigma* Cleve, 1895, p. 176.
Cocconeis oculus catis Brun, Hanna, 1951, p. 284, fig. 3 (13).

Geologic range. Pliocene to Recent.

Ecology. According to Hustedt (1933, p. 354), this is a "Litorale Meeresform, rezent bisher nur selten beobachtet; im Gebiet Europas bei Olenij im Weissen Meer!"

Cocconeis triumphis Hanna and Grant.

(Figure 182.)

Cocconeis triumphis Hanna and Grant, 1926, p. 135, pl. 14, figs. 11-13.

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39 Hendey, 1964, p. 57.

40 Kützing, 1844, p. 70, as a family Cocconeideae.

41 Kolbe, 1927, p. 29, new status and change of spelling.

Cocconeis vitrea Brun.

(Figures 183, 184.)

Cocconeis vitrea Brun, 1891, p. 19, pl. 18, fig. 2. Cleve, 1894, p. 177. Schmidt, 1894, pl. 194, figs. 10, 11.

Geologic range. Late Miocene.

Suborder Naviculineae Hendey, 1964 [42]

Family Naviculaceae Kützing, 1844 [43, 44]

Subfamily Naviculoideae Schütt, 1896 [45]

Genus **Navicula** Bory, 1822

Navicula hennedyi W. Smith.

(Figures 187, 188.)

Navicula hennedyi W. Smith, 1856, p. 93. Schmidt, 1875, pl. 3, fig. 18. Cleve, 1894, p. 57. Hustedt, 1964, pp. 453-454, figs. 1516, b, c, e-h.

Geologic range. Late Miocene to Recent.

Ecology. According to Hendey (1964, p. 213) this species is "A common littoral species on almost all European coasts."

Remarks. This species is distinguished by its broad lateral areas, semi-lanceolate, with parallel interior margins.

Navicula hennedyi var. **californica** (Greville) Cleve.

(Figure 186.)

Navicula californica Greville, 1859, p. 248, pl. 5, fig. 5.
Navicula hennedyi var. *californica* (Greville) Cleve, 1895, p. 58.
Navicula hennedyi forma *californica* (Greville) Cleve, Hustedt, 1964, p. 458, fig. 1520 [The figure is labeled "*Navicula Hennedyi* var. *californica*."]

Navicula hennedyi var. **granulata** Grunow.

(Figure 185.)

Navicula hennedyi var. *granulata* Grunow, *in* Schmidt, 1874, pl. 3, fig. 3.
"*Navicula Hennedyi* forma *granulata* Grunow, *in* A. S. Atl." Hustedt, 1964, p. 458, figs. 1519, a, b.

Geologic range. Late Miocene.

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42 Hendey, 1964, p. 58.

43 Kützing, 1844, pp. 70, 88, as a family Naviculaea.

44 Rabenhorst, 1853, pp. ix, 9, 36, change of spelling.

45 Schütt, 1896, pp. 57, 122.

Navicula lyra Ehrenberg.

(Figures 189, 190, 192.)

Navicula lyra Ehrenberg, 1843, p. 419, pl. 1, fig. 9a. Hendey, 1937, p. 344.

Geologic range. Oligocene to Recent.

Ecology. Lebour (1930, p. 209) records this species from "Brackish water." It has been recorded from "on the mud" in Chichester Harbour, by Hendey (1951, p. 50). He states (1957, p. 69) that this species is widely distributed in tropical and temperate seas. According to Hendey (1964, p. 209) this species is "Common littoral species on all British coasts and all coasts of the countries bordering the North Sea. The species favours a fairly high salinity and clean seawater, without pollution or excess organic material."

Remarks. In reference to the taxonomy of this species, Hendey (1937, p. 345) states that "in dealing with this species the multiplication of varieties and forms serves no useful purpose, and that we are called upon to regard the problem from a wider aspect."

Figure 172. *Rhabdonema biquadratum* Brun. Hypotype no. 3825 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0930 mm., breadth 0.0320 mm.

Figure 173. *Rhabdonema biquadratum* Brun. Hypotype no. 3826 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0870 mm.

Figure 174. *Rhabdonema biquadratum* Brun. Hypotype no. 3827 (CAS), from locality 866 (CAS), Monterey, California. Length 0.1236 mm., breadth 0.0340 mm.

Figure 175. *Rhabdonema biquadratum* Brun. Hypotype no. 3828 (CAS), from locality 866 (CAS), Monterey, California. Length 0.1420 mm.

Figure 176. *Rhabdonema japonicum* var. *sparsicosatum* Tempère and Brun. Hypotype no. 3829 (CAS), from locality 866 (CAS), Monterey, California. Length 0.059 mm.

Figure 177. *Entopya australis* var. *gigantea* (Greville). Hypotype no. 3830 (CAS), from locality 866 (CAS), Monterey, California. Length 0.1700 mm.

Figure 178. *Entopya australis* var. *gigantea* (Greville). Hypotype no. 3830 (CAS), from locality 866 (CAS), Monterey, California. Length 0.1700 mm. Same specimen as figure 177.

Figure 179. *Entopya australis* var. *gigantea* (Greville). Hypotype no. 3831 (CAS), from locality 1277 (CAS), Monterey, California. Length 0.1460 mm.

Figure 180. *Entopya australis* var. *gigantea* (Greville). Hypotype no. 3832 (CAS), from locality 866 (CAS), Monterey, California. Length 0.163 mm.

Figure 181. *Cocconeis decipiens* Cleve. Hypotype no. 3833 (CAS), from locality 866 (CAS), Monterey, California. Length 0.1074 mm.

Figure 182. *Cocconeis triumphis* Hanna and Grant. Hypotype no. 3834 (CAS), from locality 866 (CAS), Monterey, California. Length 0.1341 mm.

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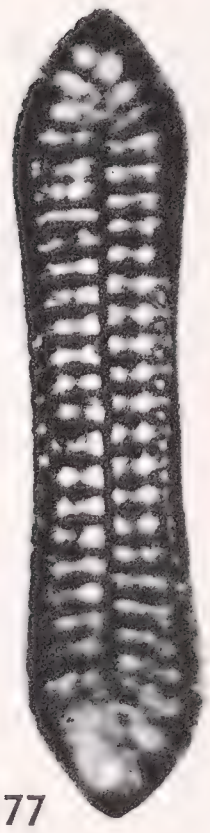

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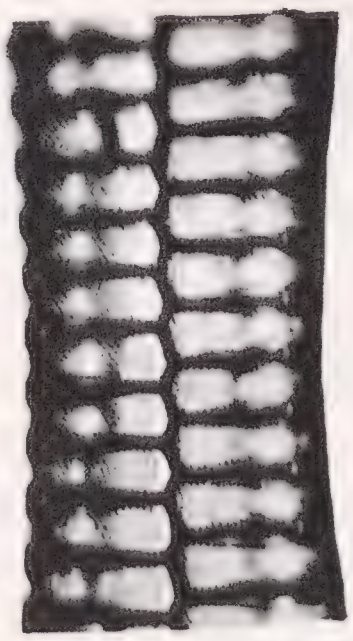

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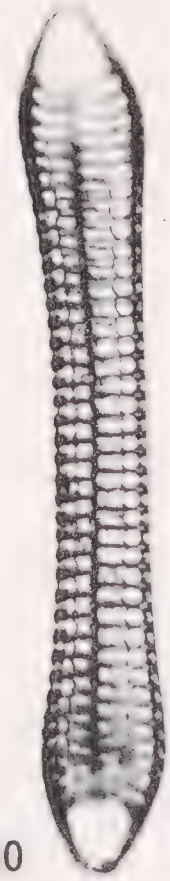

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Navicula optima Hanna.

(Figure 193.)

Navicula optima Hanna, 1932, p. 202, pl. 13, fig. 6.

Geologic range. Oligocene to Recent.

Navicula powellii var. **vidovichi** (Grunow) Cleve.

(Figure 194.)

Navicula vidovichi Grunow, 1863, p. 150, pl. 13, fig. 4. Hanna and Grant, 1926, p. 158, pl. 19, fig. 5.
Navicula powellii var. *vidovichi* (Grunow) Cleve, 1894, p. 63.

Geologic range. Late Miocene to Recent.

Navicula praetexia (Ehrenberg) Gregory.

(Figures 195-197.)

Pinnularia praetexia Ehrenberg, 1840, p. 214.
Navicula praetexia (Ehrenberg) Gregory, 1857, p. 481, pl. 1, fig. 11, Schmidt, 1875, pl. 3, figs. 31-34. Cleve, 1894, p. 55.

Geologic range. Late Miocene to Recent.

Ecology. According to Hendey (1964, p. 213) this species is "Littoral on the coasts of Scotland, Norway, west coast of Ireland and occasionally in the North Sea."

Navicula praetexia var. **abundans** Schmidt.

(Figures 198, 199.)

Navicula praetexia var. *abundans* Schmidt, pl. 129, fig. 8.
"*Navicula abundans* Schmidt." Hanna, 1928, p. 8, fig. 5.

Geologic range. Late Miocene.

Navicula spectabilis Gregory.

(Figure 191.)

Navicula spectabilis Gregory, 1857, p. 481, pl. 9, fig. 10. Hustedt, 1964, pp. 474-475, fig. 1532.
Navicula spectabilis Greville var. ? Schmidt, 1874, pl. 2, fig. 31; pl. 3, fig. 29.

Geologic range. Middle Miocene to late Miocene.

Navicula spectabilis var. **excavata** (Greville) Cleve.

(Figure 200.)

Navicula excavata Greville, 1866, p. 130, pl. 12, fig. 15.
Navicula spectabilis var. *excavata* (Greville) Cleve, 1895, p. 61. Hustedt, 1964, p. 478, figs. 1536, a, b.
Navicula oswaldii var. *hungarica* Pantocsek, 1889, pl. 25, fig. 370.

Geologic range. Late Miocene.

Genus **Diploneis** Ehrenberg, 1844

Diploneis bombus (Ehrenberg) Cleve.

Pinnularia bombus Ehrenberg, 1844, p. 84.
Diploneis bombus (Ehrenberg) Cleve, 1894, p. 90. Hendey, 1951, p. 58, pl. 8, figs. 7, 8; Hendey, 1964, p. 227, pl. XXXII, fig. 2.

Geologic range. Pliocene to Recent.

Ecology. Hendey (1951, p. 12) reports this species from the "mud flora in Chichester Harbour" (diatoms living upon the surface of mud or slime and well within the influence of sunlight). On page 8 of the same paper, he lists this species as being "solitary" in habit.

Diploneis crabro Ehrenberg.

(Figure 201.)

Diploneis crabro Ehrenberg, 1844, p. 85. Cleve, 1894, pp. 100-102. Hanna, 1951, p. 284, fig. 3 (8). Hendey, 1964, p. 225, pl. XXXII, figs. 1-3.

Geologic range. Late Miocene.

Ecology. According to Hendey (1964, p. 225), this species is "A marine species favouring a high salinity."

Remarks. Valves solitary, panduriform, strongly costate with elliptic cuneate segments. The very narrow furrows are bordered by a line of large puncta. The central nodule is quadrate or subcircular extended to produce parallel horns.

Diploneis exemta (Schmidt) Cleve.

(Figure 202.)

Navicula exemta Schmidt, 1875, pl. 11, figs. 28, 29.
Diploneis exemta (Schmidt) Cleve, 1894, p. 86.

Geologic range. Late Miocene.

Diploneis major Cleve.

(Figures 203, 204.)

Diploneis major Cleve, 1894, p. 96.
Navicula smithii Schmidt, 1875, pl. 7, figs. 18, 19, 21, 22.

Geologic range. Late Miocene to Recent.

Diploneis ornata (Schmidt) Cleve.

(Figure 205.)

Navicula ornata Schmidt, 1881, pl. 69, fig. 5. Hanna, 1928, pl. 8, fig. 6.
Diploneis ornata (Schmidt) Cleve, 1894, p. 102.

Geologic range. Late Miocene.

Diploneis ornata var. **spinifera** (Schmidt) Cleve.

(Figures 206-208, 210, 211.)

Navicula ornata var. *spinifera* Schmidt, 1882, pl. 174, fig. 25.
Diploneis ornata var. *spinifera* (Schmidt) Cleve, 1894, p. 102.

Geologic range. Late Miocene.

Diploneis smithi (Brébisson) Cleve.

Navicula smithi Brébisson, *in* W. Smith, 1856, p. 92.
Diploneis smithi (Brébisson) Cleve, 1894, p. 96. Hustedt, 1937, p. 647, fig. 1051.

Geologic range. Late Miocene to Recent.

Ecology. Hustedt (1937, p. 650) states that this species is "Im allen Meeren verbreitet und häufig, auch in schwach salzigen Gewässern des Binnenlandes hier und da auftretend, insbesondere in der Nähe der Küstengebiete. Euryhalin." According to Hendey (1964, p. 225), this species is "A widely-spread species, common in brackish and marine conditions."

Diploneis taschenbergeri (Schmidt) Hustedt.

(Figure 209.)

Navicula taschenbergeri Schmidt, 1892, pl. 174, fig. 9.
Diploneis taschenbergeri (Schmidt), Hustedt, 1937, p. 715, fig. 1090.

Geologic range. Late Miocene.

Figure 183. *Cocconeis vitrea* Brun. Hypotype no. 3835 (CAS), from locality 1277 (CAS), Monterey, California. Length 0.0700 mm., breadth 0.064 mm.

Figure 184. *Cocconeis vitrea* Brun. Hypotype no. 3836 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0620 mm., breadth 0.0430 mm.

Figure 185. *Navicula hennedyi* var. *granulata* Grunow. Hypotype no. 3837 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0550 mm., breadth 0.0340 mm.

Figure 186. *Navicula hennedyi* var. *californica* (Greville) Cleve. Hypotype no. 3838 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0510 mm.

Figure 187. *Navicula hennedyi* W. Smith Hypotype no. 3839 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0710 mm.

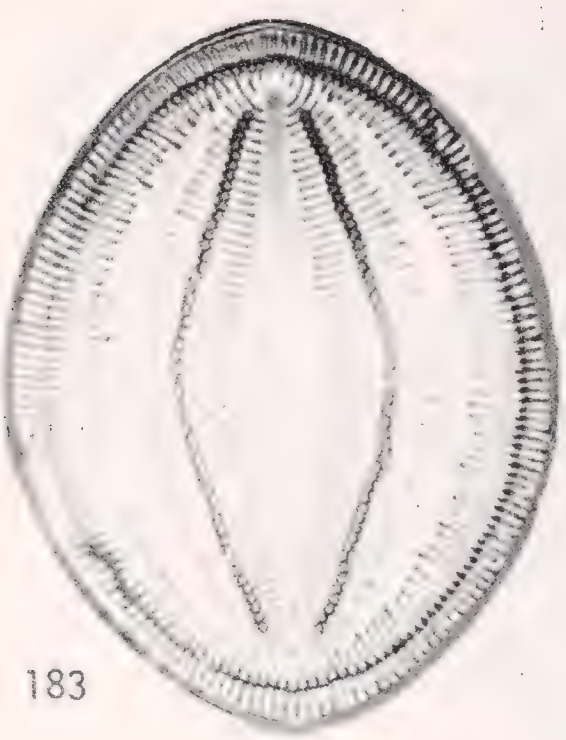
Figure 188. *Navicula hennedyi* W. Smith. Hypotype no. 3840 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0700 mm.

Figure 189. *Navicula lyra* Ehrenberg. Hypotype no. 3841 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0700 mm., breadth 0.0260 mm.

Figure 190. *Navicula lyra* Ehrenberg. Hypotype no. 3842 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0745 mm., breadth 0.0450 mm.

Figure 191. *Navicula spectabilis* Gregory. Hypotype no. 3843 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0720 mm.

Figure 192. *Navicula lyra* Ehrenberg. Hypotype no. 3844 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0970 mm., breadth 0.0440 mm.



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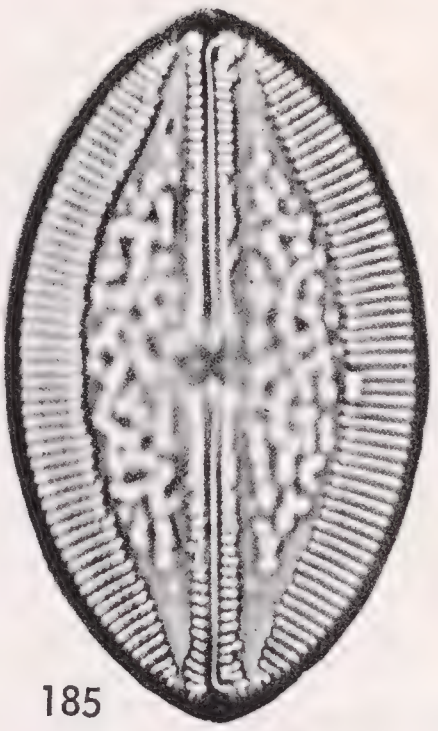

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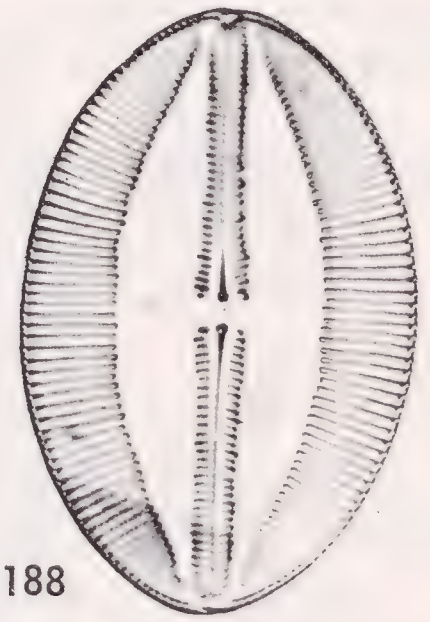

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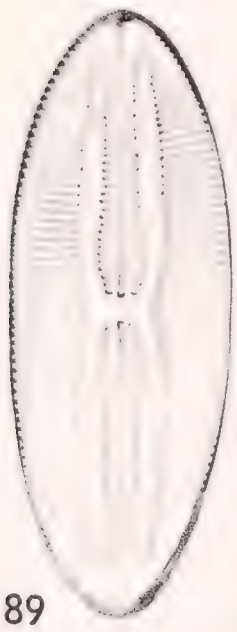

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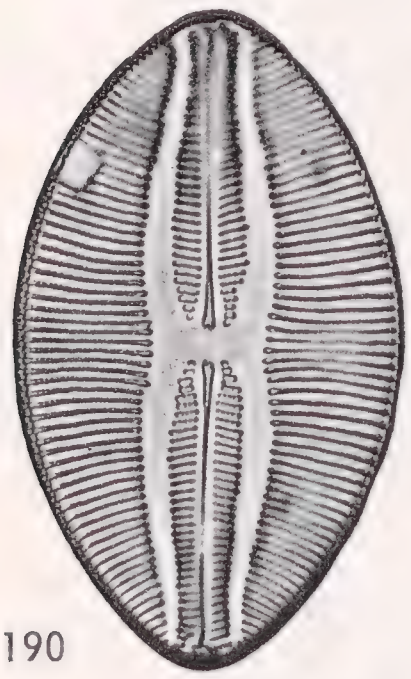

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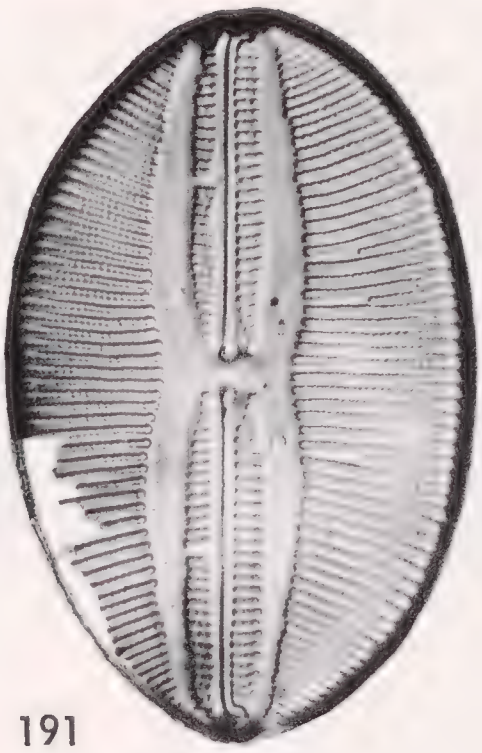

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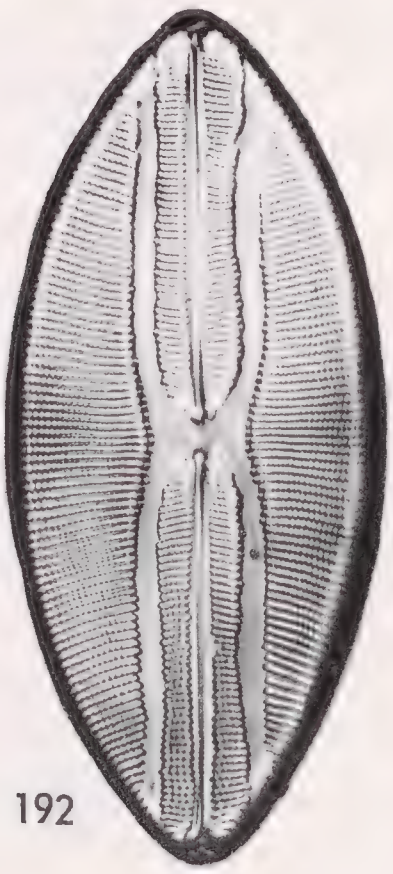

192

Family Bacillariaceae Lagerstedt, 1876 [46]

Subfamily Nitzschioideae Grunow, 1862 [47, 48]

Genus **Nitzschia** Hassall, 1845

Nitzschia pliocena (Brun), new combination.

(Figures 212, 213.)

Fragilaria pliocena Brun, 1891, p. 28, pl. 14, fig. 7. Reinhold, 1937, p. 104, pl. 12, fig. 18.

Geologic range. Early Pliocene to middle Pliocene.

Genus **Mastogloia** Thwaites, 1856

Mastogloia splendida (Gregory) Cleve.

(Figures 214-216.)

Cocconeis splendida Gregory, 1857, p. 493, pl. 9, fig. 29.
Mastogloia splendida (Gregory) Cleve. Hustedt, 1933, p. 463, fig. 883. Hendey, 1964, p. 237.
Orthoneis splendida (Gregory) Grunow, 1868, p. 15. Hanna and Grant, 1926, p. 160, pl. 19, fig. 6.

Geologic range. Late Miocene to early Pliocene.

Figure 193. *Navicula optima* Hanna. Hypotype no. 3845 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0465 mm.

Figure 194. *Navicula powelli* var. *vidovichi* (Grunow) Cleve. Hypotype no. 3846 (CAS), from locality 866 (CAS), Monterey, California. Width 0.0130 mm.

Figure 195. *Navicula praetexta* (Ehrenberg) Gregory. Hypotype no. 3847a (CAS), from locality 27295-128 (CAS), Harris grade, Purisima Hills, Santa Barbara County, Length 0.2430 mm.

Figure 196. *Navicula praetexta* (Ehrenberg) Gregory. Hypotype no. 3847 (CAS), from locality 866 (CAS), Monterey, California. Width 0.0130 mm.

Figure 197. *Navicula praetexta* (Ehrenberg) Gregory. Hypotype no. 3848 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0960 mm.

Figure 198. *Navicula praetexta* var. *abundans* Schmidt. Hypotype no. 3096 (CAS), from locality 866 (CAS), Monterey, California. Length 0.1380 mm.

Figure 199. *Navicula praetexta* var. *abundans* Schmidt. Hypotype no. 3849 (CAS), from locality 866 (CAS), Monterey, California. Length 0.1468 mm.

Figure 200. *Navicula spectabilis* var. *excavata* (Greville) Cleve. Hypotype no. 3850 (CAS), from locality 866 (CAS), Monterey, California. Length 0.1000 mm., breadth 0.0620 mm.

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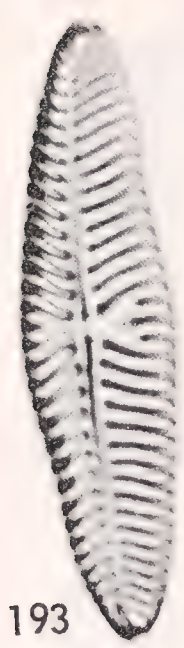
46 Lagerstedt, 1876, p. 205.

47 Grunow, 1862, p. 321, 545, as a subfamily Nitzschieae.

48 Schütt, 1896, p. 142, new status and change of spelling.



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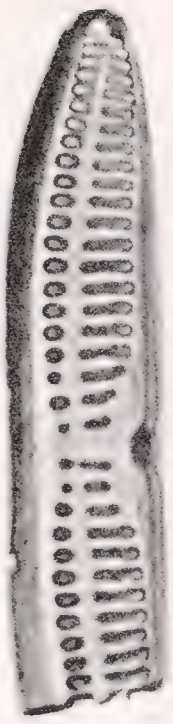

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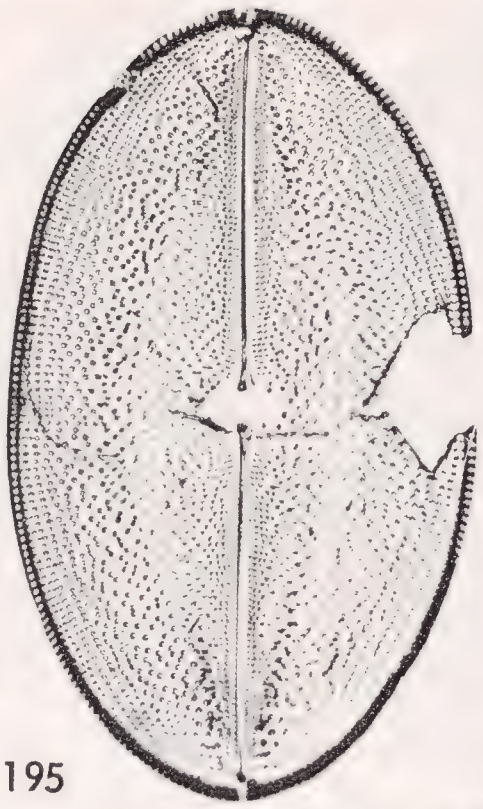

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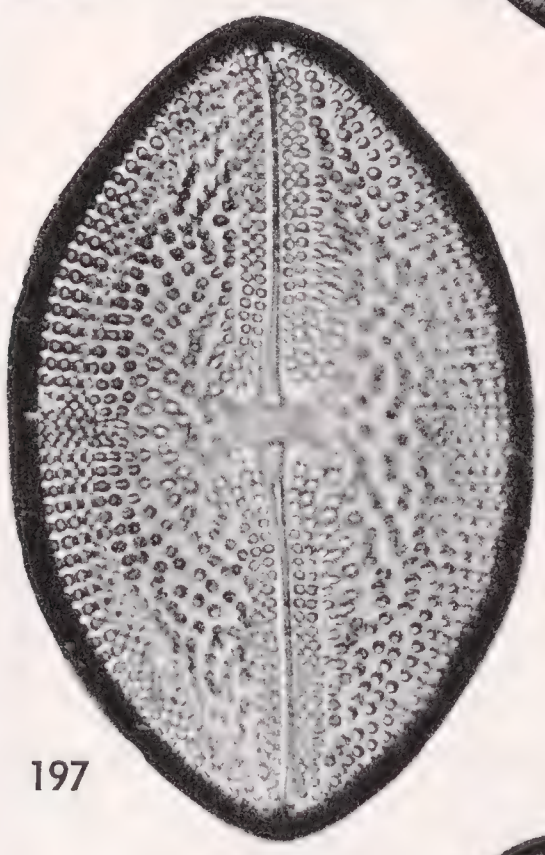

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200

Genus **Rouxia** Brun and Heribaud, 1893

Rouxia californica Peragallo.

(Figure 217.)

Rouxia californica Peragallo, *in* Tempère and Peragallo, 1910, p. 245. Hanna, 1930, p. 186-188, pl. 14, figs. 6, 7.

Geologic range. Late Miocene.

Ecology. "The presence of a species of the genus *Rouxia* at Lompoc, California, among a definitely pelagic flora, indicates that the entire genus may have been pelagic," according to Hanna (1930, p. 187.)

Family Epithemiacea Grunow, 1860 [49, 50]

Subfamily Epithemioidea Hustedt, 1914 [51]

Figure 201. *Diploneis crabro* Ehrenberg. Hypotype no. 3851 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0990 mm.

Figure 202. *Diploneis exemta* (Schmidt) Cleve. Hypotype no. 3117 (CAS), from locality 866 (CAS), Monterey, California. Length 0.1200 mm.

Figure 203. *Diploneis major* Cleve. Hypotype no. 3852 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0600 mm.

Figure 204. *Diploneis major* Cleve. Hypotype no. 3853 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0550 mm.

Figure 205. *Diploneis ornata* (Schmidt) Cleve. Hypotype no. 3097 (CAS), from locality 1277 (CAS), Monterey, California. Length 0.1266 mm., breadth 0.0400 mm.

Figure 206. *Diploneis ornata* var. *spinifera* (Schmidt) Cleve. Hypotype no. 3854 (CAS), from locality 1277 (CAS), Monterey, California. Length 0.1600 mm.

Figure 207. *Diploneis ornata* var. *spinifera* (Schmidt) Cleve. Hypotype no. 3855 (CAS), from locality 1277 (CAS), Monterey, California. Length 0.1130 mm.

Figure 208. *Diploneis ornata* var. *spinifera* (Schmidt) Cleve. Hypotype no. 3092 (CAS), from locality 1277 (CAS), Monterey, California. Length 0.2136 mm., breadth 0.0896 mm.

Figure 209. *Diploneis taschenbergeri* (Schmidt) Hustedt. Hypotype no. 3856 (CAS), from locality 866 (CAS), Monterey, California. Length 0.1270 mm.

Figure 210. *Diploneis ornata* var. *spinifera* (Schmidt) Cleve. Hypotype no. 3857 (CAS), from locality 866 (CAS), Monterey, California. Length 0.1620 mm.

Figure 211. *Diploneis ornata* var. *spinifera* (Schmidt) Cleve. Hypotype no. 3118 (CAS), from locality 866 (CAS), Monterey, California. Length 0.1520 mm.

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49 Grunow, 1860, p. 508, as a family Epithemieae.

50 Kolbe, 1927, pp. 29, 90, change in spelling.

51 Hustedt, 1914, pp. 28, 108.

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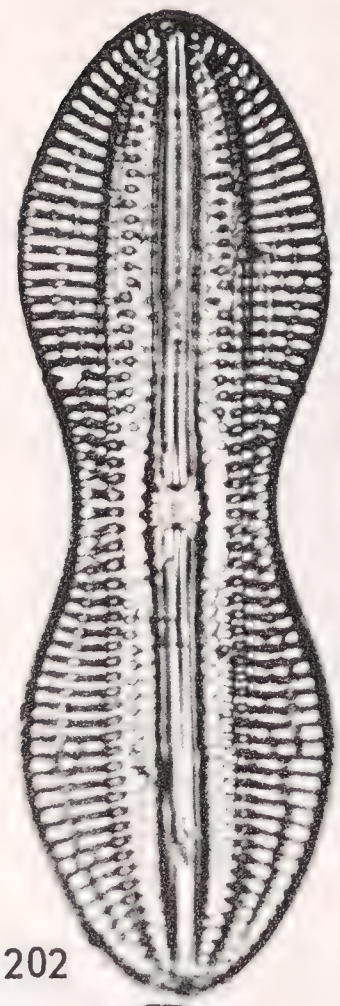

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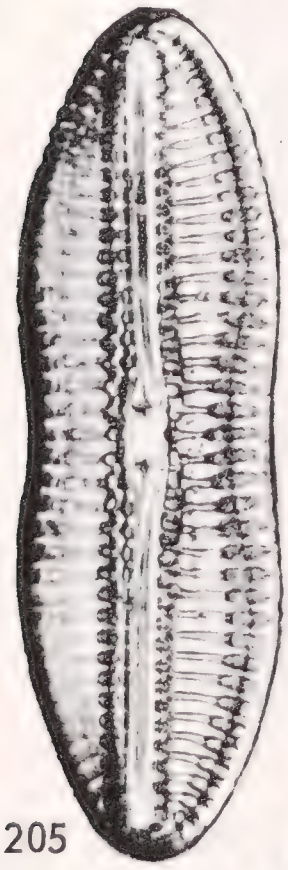

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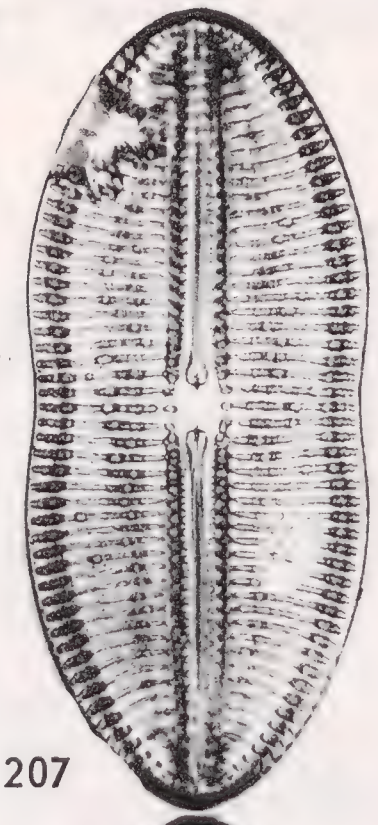

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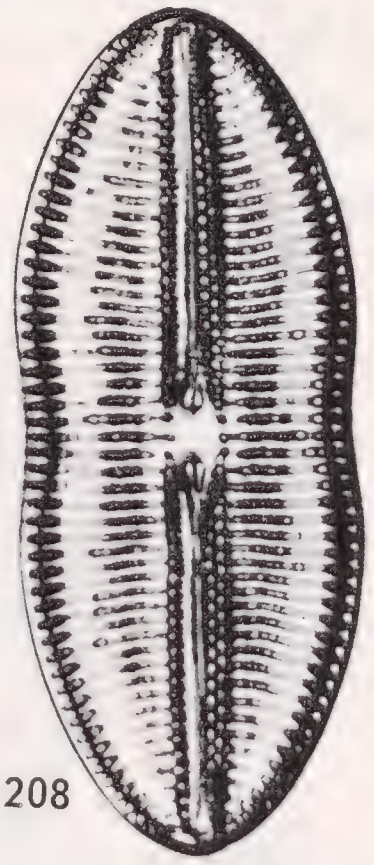

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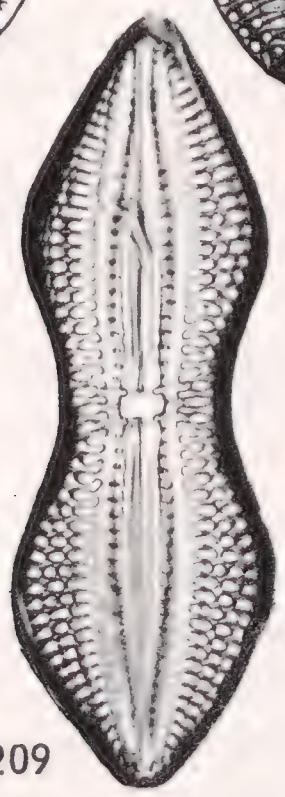

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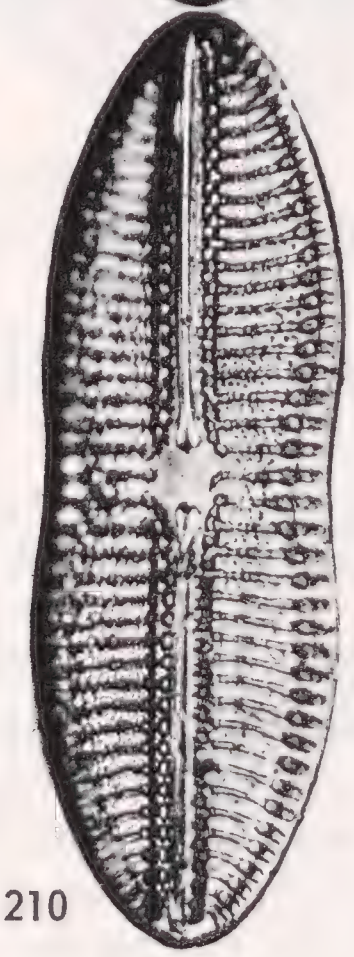

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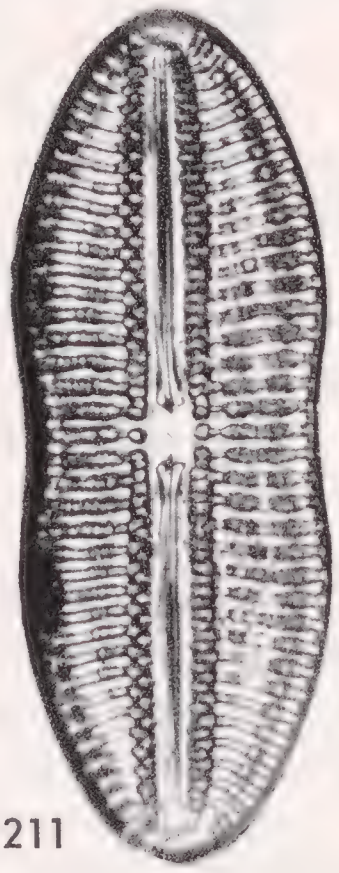


211

Genus **Denticula** Kützing, 1844

Denticula hustedtii Simonsen and Kanaya.

Denticula hustedtii Simonensen and Kanaya, 1961, p. 500, pl. 1, figs. 19-25.

Geologic range. Late Miocene to middle Pliocene.

Ecology. This genus has only one living representative which is found in the plankton in cold waters.

Remarks. Distinctive secondary pseudosepta are present.

Denticula kamtschatica Zabelina.

Denticula kamtschatica Zabelina, 1934, p. 16, figs. 7-9. Jousé, 1959, pl. 4, fig. 19.

Geologic range. Middle Pliocene.

Remarks. Distinguished by very delicate transapical striae (30 plus in 0.01 mm.) and by obscure oblique rows.

Denticula lauta Bailey.

Denticula lauta Bailey, 1854, p. 9, figs. 1, 2. Hanna, 1932, p. 188, pl. 11, fig. 1, Kanaya, 1959, p. 112, pl. 10, figs. 7-9, 15.

Geologic range. Early Miocene to middle Pliocene.

Remarks. Distinguished by the presence of distinct oblique rows, and by about 24 to 26 transapical striae in 0.01 mm.

Denticula nicobarica Grunow.

Denticula nicobarica Grunow, 1868, p. 97, pl. 1a, fig. 5. Van Heurck, 1811, pl. 49, fig. fig. 3.

Geologic range. Early Pliocene.

Remarks. Distinguished by the very coarse puncta, and by about 15-17 transapical striae in 0.01 mm.

Figure 212. *Nitzschia pliocena* (Brun), new combination. Hypotype no. 3858 (CAS), from locality 27295-29 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Length 0.0512 mm.

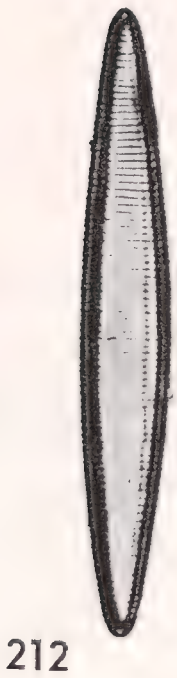
Figure 213. *Nitzschia pliocena* (Brun), new combination. Hypotype no. 3859 (CAS), from locality 27295-29 (CAS), Harris grade, Purisima Hills, Santa Barbara County, California. Length 0.0700 mm.

Figure 214. *Mastogloia spendida* (Gregory) Cleve. Hypotype no. 3094 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0900 mm., breadth 0.0720 mm.

Figure 215. *Mastogloia spendida* (Gregory) Cleve. Hypotype no. 3094a (CAS), from locality 866 (CAS), Monterey, California. Length 0.0860 mm.

Figure 216. *Mastogloia spendida* (Gregory) Cleve. Hypotype no. 3895 (CAS), from locality 866 (CAS), Monterey, California. Length 0.1580 mm.

Figure 217. *Rouxia californica* M. Peragallo. Hypotype no. 3896 (CAS), from locality 866 (CAS), Monterey, California. Length 0.0872 mm., breadth 0.0061 mm.



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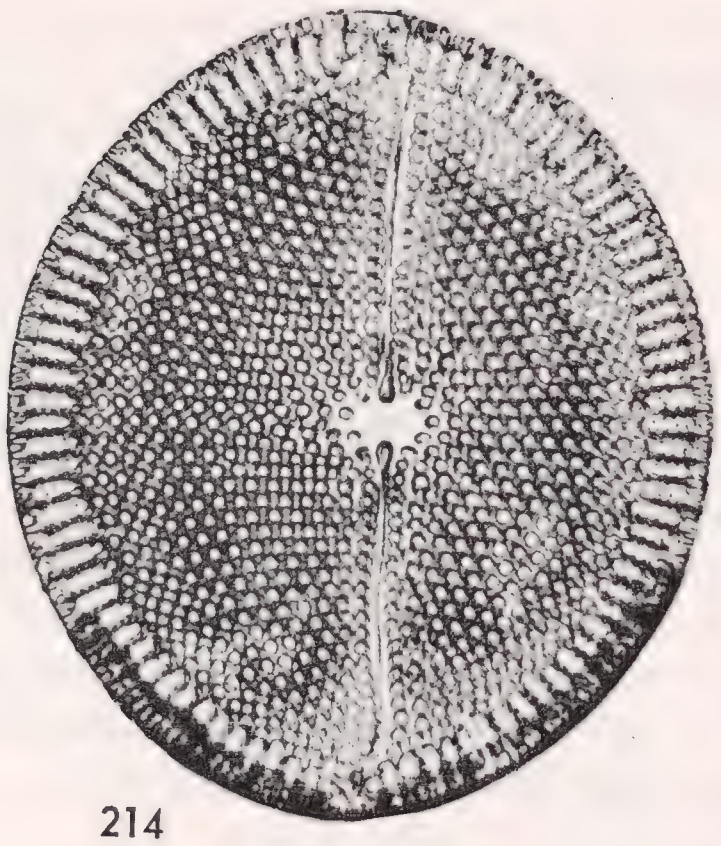

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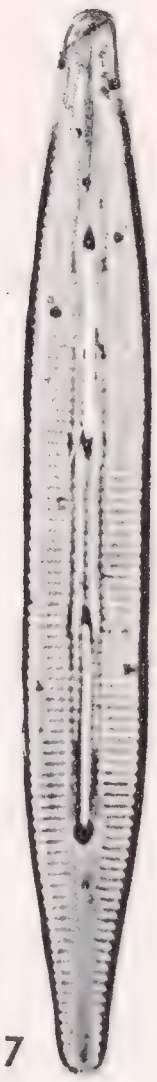

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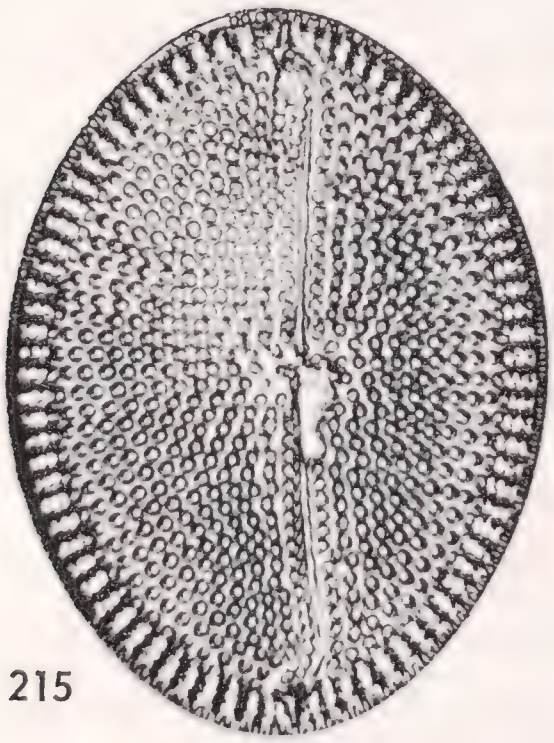

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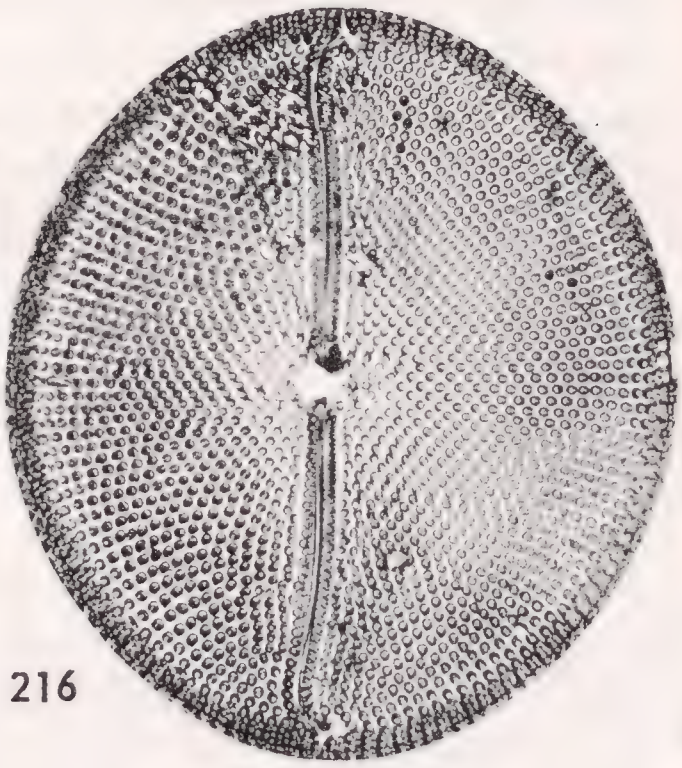

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No. 64, 4 pages, 1 figure, 1 table. November 22, 1967

A New Species of *Eremias* (Reptilia: Lacertidae) From Afghanistan

By

Steven C. Anderson and Alan E. Leviton

California Academy of Sciences, San Francisco 94118

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Two specimens of lizards referable to the genus *Eremias* were collected by Mr. and Mrs. Richard J. Clark, Field Associates of the California Academy of Sciences, during their 1964 Afghanistan Expedition. These specimens, taken from along the old Kabul-Jalalabad road, approximately 10 miles southwest of Balabagh, lead us to infer the existence of a hitherto unknown population of *Eremias* which we believe must be given nomenclatural recognition. These specimens are referred to the new taxon *Eremias aria*, which is allied to *E. velox* and its relatives.

Eremias aria Anderson and Leviton, new species.

Holotype. CAS 96204, adult male, collected 5–10 miles east-northeast of Nimla, along old Kabul-Jalalabad road, approximately 10 miles southwest of Balabagh, Afghanistan [34°19–21′ N., 70°10–15′ E.], at an elevation of about 3,500 feet, by Richard J. and Erica D. Clark, 31 July 1964.

Paratype (1). CAS 96205, juvenile, same data as holotype.

Diagnosis. Ventrals in 12 to 14 oblique longitudinal series; subocular not bordering mouth; frontal and supraoculars not separated by a complete row of granules; three nasals, the lower in contact with three anterior supralabials; occipital absent; anterior enlarged supraocular longer than its distance from second loreal; first transverse row of pectoral scales twice as long as broad, twice as long as succeeding rows; 17 to 18 femoral pores on each side, the two series separated by a space not exceeding ¼ the length of each; toes with a single series of unicarinate subdigital lamellae.

Description of holotype. Head and body moderately depressed. Head (tip of snout to angle of jaws) 1¾ as long as broad, its length 3⅓ times in snout-vent length, its depth equal to its distance between anterior corner of eye and tympanum; snout pointed with swollen nasals, as long as postocular part of head; canthus rostralis strong, loreal region vertical; a distinct lanceolate

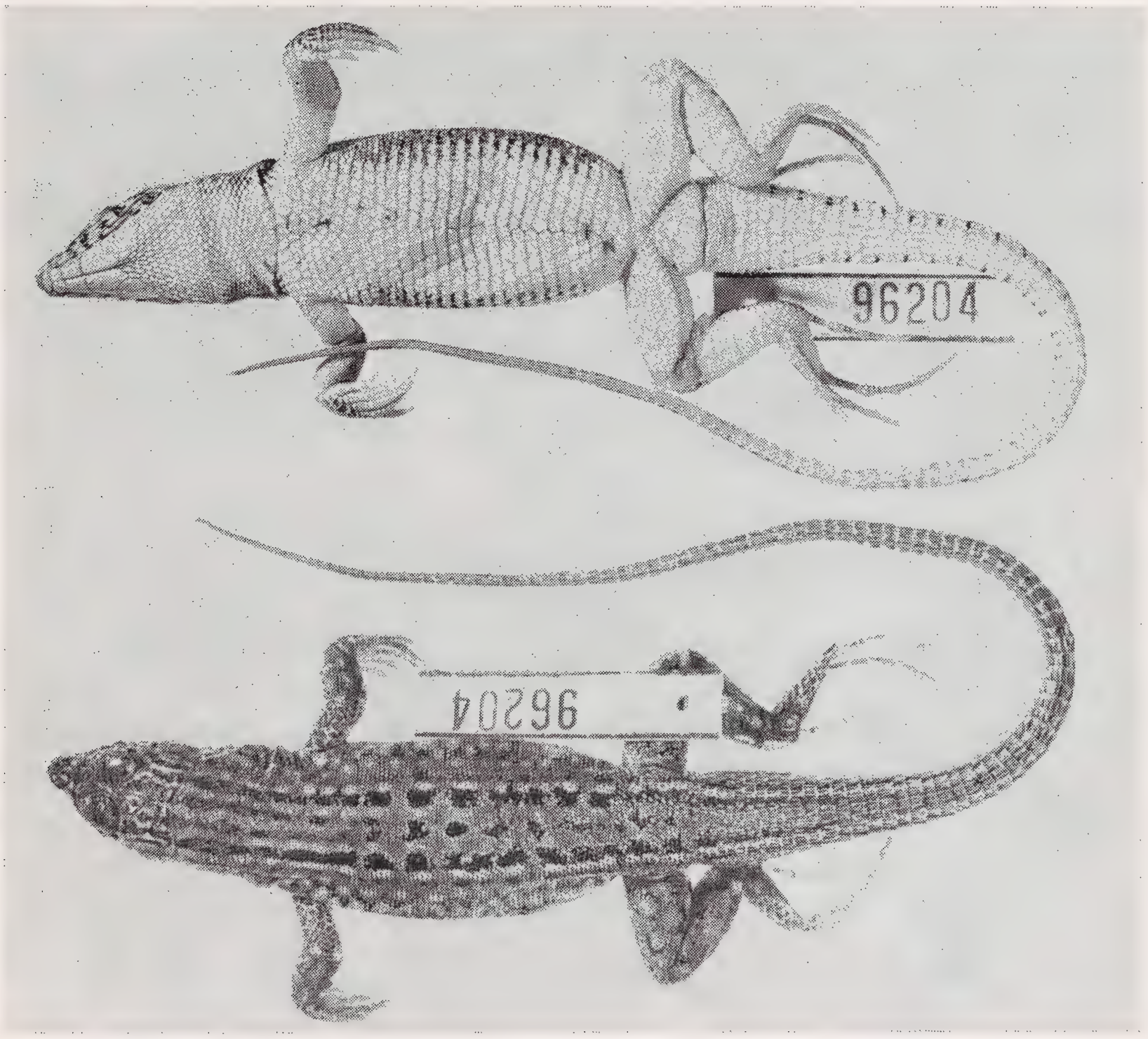

FIGURE 1. Holotype of *Eremias aria* Anderson and Leviton, new species [CAS 96204].

concavity on upper surface of snout, from anterior half of frontonasal to posterior half of frontal. Pileus (cluster of all enlarged scales on crown of head) twice as long as broad. Neck as broad as head. Hind limb reaches to between eye and ear; foot 1⅕ as long as head; toes slender, compressed. Tail slightly more than twice as long as head and body, cylindrical, and depressed at base.

Anterior head shields smooth and convex, frontoparietals, interparietal, and parietals slightly rugose; nasals in contact behind the rostral, the suture between them about ½ length of frontonasal, which is 1⅓ times as broad as long; prefrontals 1½ times as long as broad, forming a median suture; frontal as long as its distance from end of snout, slightly more than twice as long as broad, narrow behind; parietals as broad as long; interparietal slightly more than ½ times as long as frontoparietals; no occipital. Two large supraoculars, the first longer than the second, and much longer than its distance from the second loreal, the space in front of it filled by three small shields and a few granules; a small, band-like posterior supraocular; frontal not separated from supra-

TABLE 1. *Counts and measurements of specimens of* Eremias aria *Anderson and Leviton.*

Number	*Sex*	*Length (in mm.)*		*Dorsal scales*	*Ventrals*		*Gulars*	*Femoral pores*
		Snout-vent	*Tail*		*Longitudinal*	*Transverse*		
96204	♂	61	126	59	12	28	25	18
96205	yg	32	—	55	14	29	23	17

oculars by granules; six superciliaries, first longest; a series of granules between supraoculars and superciliaries. Rostral slightly broader than high, narrower beneath than above; three nasals, the lower in contact with three supralabials and just touching rostral; anterior loreal as long as high, shorter than the second; subocular keeled below eye, not bordering mouth, resting on sixth, seventh, and eighth supralabials. Temporal scales granular, smooth; tympanic shield present; no auricular denticulations. Lower eyelid translucent, covered with small scales.

Five pairs of chin shields, anterior three in contact on the midline, fifth separated from infralabials by two rows of scales. Twenty-five gular scales in a straight line between the symphysis of the chin shields and the collar. Gular fold distinct. Collar curved, free, serrated, composed of 12 plates.

Scales granular, smooth, 59 across middle of body. Ventral plates broader than long (except for outermost series, which are as long as broad), forming oblique longitudinal series, in 28 slightly angular transverse rows, the longest of which contains 12 plates; first transverse row of pectoral scales twice as long as broad, twice as long as succeeding rows. Preanal region with an enlarged median plate posteriorly.

Upper surface of arm with rhombic, weakly keeled scales which are larger than the largest gulars. Scales on upper surface of tibia similar to dorsals, but slightly smaller; enlarged plates covering almost entire lower surface of tibia; 18 femoral pores on each side, the two series separated by a single scale. Subdigital lamellae unicarinate, 25 under the fourth toe.

Upper caudal scales oblique, obtusely pointed, or truncate, strongly and diagonally keeled, lower, at the base, smooth; 28 scales in the fifth whorl behind the postanal granules.

Color (in alcohol, initial preservation in formalin) gray above with four black stripes on neck, a median series of black spots on back resulting from fusion and interruption of the two paravertebral neck stripes; a black dorsolateral stripe on each side, interrupted, bordered laterally by a white stripe, similarly interrupted; four rows of lateral indistinct small white spots on each side, interspersed with black; head gray, lines on neck extending forward onto parietals; scattered black marks on dorsal head scales; labials white with black markings; dorsal surface of limbs gray with lighter spots; venter white, the lateral ventral plates marked with black.

Remarks. The dorsal pattern in the paratype, a small juvenile, is formed of alternating dark and light stripes, ten black stripes on neck, nine on body, the ventrolateral being least distinct. On the flanks the dark stripes coalesce to interrupt the white stripes, forming two lateral series of white spots. The limbs are black, spotted with white; ventral surfaces white (bluish in life).

Also in the paratype, the loreals are fused, there being a single loreal on each side, and the first large supraocular is fused with the presupraocular small scales to form a very large scale, separated from the loreal by a single small scale.

This new form differs from *Eremias velox, E. nikolskii,* and *E. regeli,* in having the subocular well separated from the mouth, and in the color pattern. It differs from *E. intermedia,* to which it may be related also, in the very narrow separation of the two series of femoral pores. It differs further from *E. velox* and *E. regeli* in having a single row of subdigital lamellae.

We have also compared our new species with a specimen of *E. nigrocellata,* based on Field Museum of Natural History 141547, from 10 miles south of Mahneh, Khorassan, Iran. The Iranian specimen differs from the new form in having the two series of femoral pores broadly separated; the first transverse row of pectoral scales are not twice as long as broad, nor markedly longer than succeeding rows, the plates on the lower surface of lower leg are not as broad as in the new form, and the dorsal light spots are clearly ringed with black.

Although within the apparent range of *E. velox persica* (though *E. v. persica* has not been taken in the vicinity of Nimla), it is separated from the known ranges of the other related species by the Hindu Kush. The fact that this form appears to have its closest affinities with species in the USSR, on the other side of the Hindu Kush, raises important zoogeographic questions.

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No. 65, 8 pages, 17 figures. June 27, 1968

A New Species and Subspecies of *Galvezia* (Scrophulariaceae) from the Galápagos Islands

By

Ira L. Wiggins

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By
Ira L. Wiggins
Professor Emeritus, Natural History Museum, Stanford University

During January and February, 1967, the writer, assisted by Dr. Duncan M. Porter, collected vascular plants in the Galápagos Islands. This field work was done as part of the program of research under National Science Foundation grant GB-5254, administered by the California Academy of Sciences.

On 29 January 1967, the writer and Dr. Porter had walked inland approximately 2 kilometers from Caleta Tagus (Tagus Cove) on Isla Isabela (Albemarle Island), toward the foot of the prominent peak slightly north of east from Caleta Tagus. On the northeasterly side of a lava ridge we found several rounded shrubs that were notable owing to their deep green, sub-fleshy leaves and their waxy white flowers borne on short lateral twigs near the tips of the arcuately curving main branches. The plants obviously belonged in the Scrophulariaceae, but we were uncertain about their generic relationship.

Study of the specimens after our return to the United States showed that the shrubs represented an undescribed species of *Galvezia* Dombey.

Galvezia leucantha species novum.[1]
(Figures a–i, k, l.)

Frutex 1–1.5 m. altus latusque, ramis gracilibus arcuatis ramulosis, ramulinis congestis 3–6 cm. longis; cortex ramorum brunneus laevis, lenticellis minutis ellipticis 0.2–0.4 mm. longis; folia opposita vel alternata; petioli 4–10 mm. longi minute alati glabri vel sparsim puberuli; laminae foliorum ellipticae vel elliptico-ovatae 8–15 (20) mm. latae, 2–5 cm. longae glabrae crassiusculae integrae, nervaturis pinnatis inconspicuis, foliis ramulinorum parvulis vulgo 4–10 mm. longis; flores numerosi albi axillaribus solitariis, pedicellis gracilibus 8–12 mm. longis glabris, sepalis paene discretis lanceolatis vel lanceolato-ovatis 4–6 mm. longis

* The Charles Darwin Research Foundation Contribution no. 73.

[1] The kindness of Dr. Rimo Bacigalupi in suggesting the specific epithet, meaning, "white-flowered," is appreciated greatly.

glabris; corolla ceraceo-alba aliquantum personata, tubo 8–10 mm. longo puberulo externo, labio supero bilobato 5–6 mm. longo, labio inferiore trilobato plicis palatorum dense papillatis circa 2 mm. longis; stamina fertiles didynami 4 imo corolla tubo inserta, paribus staminorum brevibus circa 6 mm. longis lobii superioris opposita inserta, filamentis gracilibus laevis, paribus staminorum longioribus circa 8–9 mm. longis sub sinum lobis labii inferioris affixa faucem corollae aequantem, filamentis prope basem plus minusve dilatatis papillatisque; stamen sterilis circa 2 mm. longus in fovea lunari vadoso imo corolla tubo sub sinu labii superioris inserta; stylus gracilis 2–3 mm. longus saepa ad maturitatem fructus persistens; stigma capitatum plus minusve bilobatum; capsula late ovoidea vel globosa 5–6 mm. longa glabra; semina numerosa atrata 0.7–0.8 mm. longa ad apicem rotundata raro truncata ad basem acuta irregulariter cristata.

Type. Eastern side of ridge near foot of Tagus Cove Mountain, northeast of Caleta Tagus (Tagus Cove), about 1.5 to 2 kilometers from the beach, altitude about 95 meters, Isla Isabela, Islas Galápagos, Ecuador, 29 January 1967, *Ira L. Wiggins* and *Duncan M. Porter 247* (holotype, CAS).

Rounded, somewhat straggly, much-branched shrubs 1–1.5 m. tall and about as wide, the branches often arcuately curved and bearing numerous, rather crowded lateral twigs 3–6 cm. long that bear leaves much smaller than those on the main branches; bark on older twigs and branches dull brownish tan, with many small, elliptic, darker brown lenticels 0.2–0.4 mm. long, the surface glabrous and smooth, neither exfoliating nor shining; main leaves on larger branches elliptic to elliptic-ovate, acute at the apex, rounded to obtuse at the base, 8–15 (20) mm. wide, 2–5 cm. long, glabrous, rather thick and firm, dark green, margins entire, nerves pinnate and inconspicuous (leaves arranged alternately and in opposite pairs often occuring on the same branch); petioles 4–10 mm. long, faintly winged toward juncture with the blade, glabrous or bearing a few widely scattered, simple, spreading, minute hairs; leaves on lateral twigs narrower in relation to width and much smaller than those on main branches, often only 1.5–2.5 mm. wide, 4–10 mm. long, narrowly acute at both ends; flowers borne singly in axils of reduced leaves on lateral twigs; pedicels very slender, 8–12 mm. long at anthesis, to 22 mm. long in fruit, abruptly bent downward from base of calyx cup; calyx lobes unequal, connate only at base, free through most of their length, 4–6 mm. long, lanceolate to lance-ovate, the adaxial pair the longest, the abaxial one the shortest, all glabrous throughout, a marked groove between the cup of calyx and each sepal; corolla waxy white, in bud the adaxial lip outermost, central lobe of the lower lip innermost and overlapped by the two lateral lobes of that lip, outer surfaces of both tube and lips moderately puberulent with straight, spreading, minute hairs, about one-third of these gland-tipped, the rest non-glandular and pointed at the tip; corolla 10–12 mm. long at anthesis, the throat only slightly ampliate, the tube 8–10 mm. long, upper lip 5–6 mm. long, nearly straight but turned backward at an angle of about 60 to 70 degrees,

FIGURES a–i, k, l. *Galvezia leucantha* subsp. *leucantha*. Figure a, habit of flowering branch, × ½; figure b, bud just before anthesis, × 2.5; figure c, flower at anthesis, × 2.5; figure d, part of base of corolla showing pit and insertion of abortive stamen, × 12; figure e, corolla split and laid open to show relationship of stamens and corolla lobes, × 2.5; figures f, g, representative leaves, × 1; figure h, epidermal hairs from outside of corolla tube, × 50; figure i, segment of basal part of stamen filament with glandular hairs, × 25; figure k, mature ruptured capsule, × 3; figure l, seed, with irregular cristate ridges, × 25.

FIGURE m. *Galvezia leucantha* subsp. *pubescens*. Average leaf × 1.

FIGURES n–r. *Galvezia fruticosa*. Figures n, o, flower and corolla of *G. fruticosa*, × 2.5; figure p, corolla split and laid open to show relationships among stamens, corolla tube, and lobes, × 2.5; figure q, average leaf, × 1; figure r, seed, with truncate apex and base, × 25.

sinus between lobes of upper lip extending about to middle of lip; lower lip 3-lobed, the sinuses between the lobes about as deep as the sinus of the upper lip, the central lobe somewhat cucullate, an ellipsoidal palatal fold extending

inward about 2–2.5 mm. from the orifice of the throat just below each sinus of the lower lip, these folds closely beset with stout, short, 1–3-celled gland-tipped hairs or papillae; functional stamens 4, didynamous, a fifth non-functional stamen opposite the sinus in the upper lip and inserted in a shallow, lunate pit about 2 mm. above the base of the corolla tube; filaments of functional stamens slender, those of the shorter pair inserted opposite the lobes of the upper lip near base of the corolla tube, smooth, devoid of hairs or papillae, the longer pair inserted opposite the sinuses between the central and lateral lobes of the lower lip near base of corolla tube, slightly dilated on the lower 2–3 mm. and bearing numerous small papillae like those on the palatal folds over the dilated portion, otherwise smooth and glabrous, barely exceeding the corolla tube so anthers of the longer pair of stamens usually exserted about one-half their length; styles filiform, 2–3 mm. long, persistent until maturity of the fruit; stigma captitate or faintly bilobed; capsule broadly ovoid to subglobose, 5–6 mm. long, glabrous, dehiscing by irregular, subterminal pores, the apices usually pointing downward owing to the sharp bend at the tip of the pedicels; seeds numerous, dull black, 0.7–0.8 mm. long, rounded, obtuse, or very rarely truncate at the apex, acute or rarely rounded-obtuse at the base, with 3 to 5 rather smooth faces flanked by irregular, slightly sinuous, cristate ridges running from base to apex, the faces sometimes bearing minute conical papillae, the cristate ridges either black or dark gray.

The most striking feature differentiating this species from those heretofore placed in *Galvezia* is the waxy white corolla. All species of *Galvezia* described previously have deep red corollas, none of the shades within their range even approaching pink or white. Were albino flowers known to occur sporadically among the species of *Galvezia* occurring in southern California, northwestern Mexico, or in Ecuador and Peru, one might consider the Galápagos population a variant of a mainland species, if this character alone were used to separate the island plants from those of the mainland. But the Galápagos specimens from Isla Isabela possess several additional characters that clearly separate them from their nearest relative on the mainland, *G. fruticosa* Gmelin. The calyx lobes of *G. leucantha* are considerably more slender, longer in relation to their width, and longer *in toto* than those of *G. fruticosa*. Whereas the calyx and pedicels of *G. fruticosa* are closely glandular-puberulent, the calyces and pedicels of *G. leucantha* are wholly glabrous (figs. a, b, and c). The posterior pair of stamens in *G. leucantha* are papillate for only 2–3 mm. just above the point of their attachment to the corolla tube but are glabrous and without papillae above this zone (fig. e). In contrast, the comparable stamens in *G. fruticosa* are papillate not only near their bases but also over about 1.5–2.5 mm. just below the anthers (fig. p).

The rudimentary sterile filament in the flowers of *G. leucantha* is inserted in a shallow, lunate pit about 1–2 mm. above the base of the corolla tube (figs. d,

e). That of flowers of *G. fruticosa* is affixed to the unmodified, pitless wall of the corolla tube (fig. p).

The pubescence on the outer surface of the corolla tube and the exterior of the lobes in *G. leucantha* is made up of two kinds of hairs—straight to slightly curved, 3–5-celled, non-glandular, pointed hairs, and about one-third as many gland-tipped hairs of about the same length (fig. h). In *G. fruticosa* the hairs are as much as twice as long as those in *G. leucantha*, are more closely crowded, and nearly all of them are gland-tipped (compare figs. b, c, and d, with figs. n and o).

General inspection suggests that the width/length ratio of the leaf blades in *G. leucantha* is lower than that in *G. fruticosa*. A small number of measurements showed this width/length ratio in *G. leucantha* to range ⅓ to ½, whereas in *G. fruticosa* the ratio is about ⅔ (compare figs. f and g with fig. q). A larger sampling is needed before such ratios can be considered statistically significant.

Finally, the seeds of *G. leucantha* are obovoid in shape, nearly always with a rounded apex and acute base, with irregular, moderately sinuous cristate ridges running from base to apex, and often leaving smooth areas between the ridges (fig. l). On the other hand, the seeds of *G. fruticosa* are predominantly quadrate in cross section, with very narrow, often barely perceptible ridges along the angles and a few or none on the faces. The apex and base of seeds of *G. fruticosa* are almost always truncate (fig. r).

On 20 December 1905, Alban Stewart collected three numbers of *Galvezia* on Isla Rábida (Jervis Island). In his report (Stewart, 1911, p. 141) he referred these specimens to *G. fruticosa* Dombey, but added the note, "No flowering specimens were secured, so that the species is somewhat doubtful."

He made this statement because he had only one of the three sheets collected on Isla Rábida with him during his studies of the Galápagos flora at Harvard University. Actually two of the three sheets deposited in the herbarium of the California Academy of Sciences have flowers attached to the lateral twigs. One of these flowers was soaked until flexible, in order to examine the character of the lobing, insertion of stamens, and nature of the filaments. This flower proved to have been white when fresh, although it had darkened considerably during drying and with age. It also had the longer pair of stamens with papillae near the base but without them near the anthers, and its rudimentary stamen was inserted in the distinctive lunate pit rather than on the smooth inner wall of the corolla tube. The Isla Rábida material is definitely within the specific limits of *G. leucantha*, and is distinct from *G. fruticosa*. However, it differs from the specimens collected on Isla Isabela in that its twigs, young branches, leaves, pedicels, calyces and outer surfaces of the corolla are closely invested with glandular pubescence made up of hairs one and one-half times to twice as long as those on the outer corolla surface of *G. leucantha* subsp. *leucantha*. Inter-island differentiation has occurred owing to the operation of influences not yet known.

This differentiation makes advisable the subspecific recognition of the Isla Rábida plants.

Galvezia leucantha Wiggins subsp. **pubescens** varietas novum.
(Figure m.)

A subsp. *leucantha* foliis ramulis calycibus et tubo corolla dense glanduloso-puberulis differt.

Type. Occasional near the shore and from 500–950 feet, Jervis Island (Isla Rábida), 20 December 1905, *Stewart 3441* (holotype CAS).

The specimens from Isla Rábida differ from our collection from Isla Isabela in the characters mentioned above. Further, the single flower soaked up during the study of the material had larger, and more numerous stipitate glands on the inner surface of the upper lip of the corolla than was shown on any of the flowers from the Isla Isabela collection. This characteristic was not included in the diagnosis because of the small sampling made, and the presence of a few scattered glands of similar type on an occasional flower in the Isla Isabela material.

Specimens examined. Isla Rábida—occasional near the shore and from 500–950 feet, *Stewart 3440* (CAS, GH), *3441*, *3443* (CAS).

I believe that there is a significant relationship between the evolution of a species with white flowers within the generic framework of a plant that in all other areas has red flowers, and the absence of hummingbirds in the habitat of the white-flowered population in contrast to the presence of hummingbirds in all parts of the range of the red-flowered species that occupy the mainland habitats. No hummingbird has been observed in the Galápagos Islands and their absence no doubt is attributable to the 500 miles of open sea between the Galápagos Islands and the nearest point on the mainland of South America. The hummingbirds, which are active only during daylight hours, are important pollinating agents among the species of *Galvezia* growing on the mainland of South America as well as among the species native in the southwestern United States and adjacent Mexico. In the Galápagos Islands the night-flying moths and butterflies have filled the chief niche as pollinating agents for the majority of the flowers with tubular corollas. These moths fly between dusk and dawn. Thus the Galápagos representatives of *Galvezia* grow in an environment in which there is little or no evolutionary pressure toward brightly colored flowers, and where the emphasis is upon flowers that are readily visible to night-flying insects when light intensity is very low. Under such conditions, it seems logical for plants to evolve flowers whose corollas are white or pale yellow and to rarely produce those with red or deep blue blossoms.

A hasty check of the flowering plants that had become established in the Galápagos Islands prior to the arrival of modern man shows that few of them had red or blue flowers. Many have cream, pale yellow, golden yellow, or white flowers. Only a few (*e.g.*, *Cuphea, Sesuvium, Salvia*) had pale lavender to pink

corollas. An extensive study of the relationships among the plants and their insect visitors in the Galápagos Islands might be highly productive.

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OCCASIONAL PAPERS

OF THE

California Academy of Sciences

No. 66, 13 pages, 13 figures. June 27, 1968

Descriptions of New Species of Gastropods from Clipperton Island

By

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SAN FRANCISCO

PUBLISHED BY THE ACADEMY

1968

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Descriptions of New Species of Gastropods from Clipperton Island

By
Leo G. Hertlein* and Edwin C. Allison**

A collection of molluscan shells from Clipperton Island in the eastern Pacific (Latitude 10° 17′00″ N., Longitude 109° 13′00″ W.) assembled by the junior author in 1958 (see Allison, 1959) contained a number of species of gastropods, many of which were recorded in an earlier paper by the present authors (Hertlein and Allison, 1966). Species of gastropods not included or cited with provisional identification in that paper have received additional study and, as they apparently are undescribed new forms, descriptions of them are furnished in the present paper.

Acknowledgments are due several individuals who aided us in the present study. Dr. Alison Kay, Department of Science, University of Hawaii, compared specimens of the new *Colubraria* with others in the Bernice P. Bishop Museum in Honolulu, Hawaii. Dr. and Mrs. G Dallas Hanna, California Academy of Sciences, aided in the measurement of specimens and in the retouching and arrangement of the illustrations. Mr. Allyn G. Smith, of the same institution, aided with the identifications and contributed constructive criticism of the manuscript; Mr. Maurice Giles, California Academy of Sciences, prepared the photographs used to illustrate two of the species. The line drawings reproduced as text figures were made by Mrs. May Blos, scientific illustrator, University of California. An exchange of specimens with Dr. William K. Emerson and Mr. William Old, Jr., American Museum of Natural History, made available specimens of *Colubraria* for comparative study.

The holotype specimens of the new species and all other specimens illustrated in this paper are in the University of California Museum of Paleontology, Invertebrate Type Collection, Berkeley, California. Paratypes, where available, are in the California Academy of Sciences, Department of Geology, Type Collection.

* Curator of Invertebrate Paleontology, California Academy of Sciences.
** Associate Professor, Department of Geology, San Diego State College.

Description of Species

Cyclostremiscus solitarius Hertlein and Allison, new species.

(Figure 1.)

Cyclostrema cingulifera A. Adams, Hertlein and Allison, The Veliger, vol. 9, no. 2, p. 139, 1966.

Not *Cyclostrema cingulifera* A. Adams, Proc. Zool. Soc. London for 1850, p. 43, issued November 12, 1850. "Hab. Dumaguete, island of Zebu, 4 fathoms; H. C. (Mus. Cuming.)."

Description. Shell very small, discoid, nuclear whorl followed by 2 regularly expanding rounded whorls; spire deeply depressed, umbilicus broadly funnel-shaped; last whorl with a sharp, serrate, spiral keel on the periphery, two similar ones, one a short distance above, the other below the central keel, also on each side above the margin of the umbilicus is a spiral row of fine nodes and at the margin of the umbilicus there is a trace of a very fine spiral threadlet; the surface between the keels is sculptured with very fine spiral striae, and on the early portion of the first whorl there are faint transverse markings between the basal and the succeeding keel; peristome circular, the margin fairly thick, slightly flaring; operculum circular, the exterior with faint traces of concentric lines. Maximum diameter .74 mm., minimum diameter .57 mm., maximum height of body whorl .38 mm.

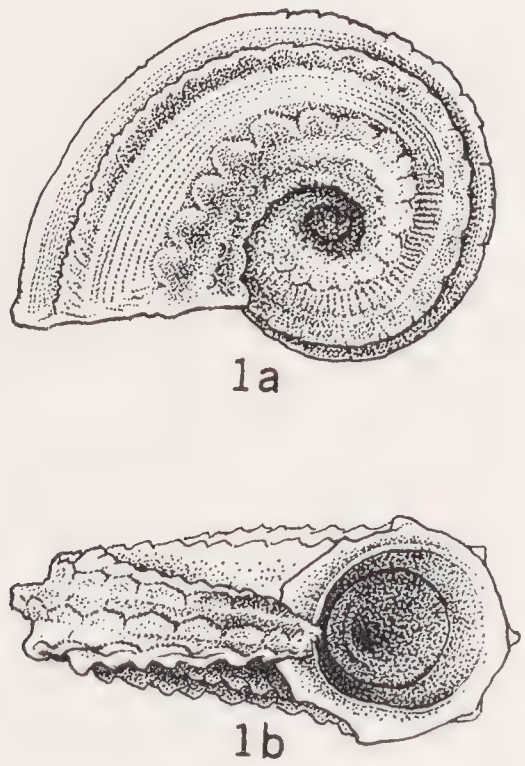


Figure 1. *Cyclostremiscus solitarius* Hertlein and Allison, new species. Holotype no. 37121 (UC), from Clipperton Island. 1a, basal view; 1b, apertural view; maximum diameter 0.74 mm.

Holotype no. 37121, University of California Museum of Paleontology, Invertebrate Type Collection, from Locality B-4241, outer portion of intertidal bench with prominent *Pocillopora*, brown algae, and slight amounts of coralline algae, Clipperton Island.

Remarks. The generic assignment of this new species may be open to question, but it bears a general resemblance to some species of *Cyclostremiscus*. The general shape and character of coiling resembles that of the form described as

Cyclostremella venezuelana Weisbord (1962, p. 136, pl. 9, figs. 7, 8; pl. 12, figs. 20–22), from strata of late Cenozoic age. However, according to Moore (1966, p. 480) the Venezuelan species is not referable to the genus *Cyclostremella*.

The illustration given by Moore of *Cyclostrema humilis* Bush, the type species of *Cyclostremella*, reveals the presence of a slight depression below the suture and the operculum is somewhat elongated and paucispiral. The whorls of the new species from Clipperton Island are rather evenly rounded and the operculum is circular in outline.

Amphithalamus trosti Hertlein and Strong.

(Figure 2.)

Amphithalamus trosti Hertlein and Strong, Allan Hancock Pac. Exped., vol. 2, no. 12, p. 228, pl. 21, fig. 2, August 21, 1939. "Dredged in from 3 to 9 fms. in Bahia Honda, Panama."

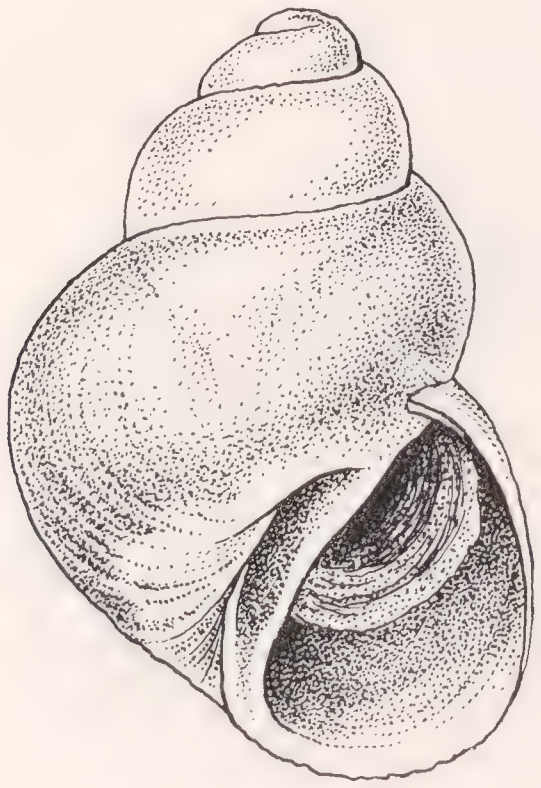


Figure 2. *Amphithalamus trosti* Hertlein and Strong. Hypotype no. 37122 (UC), from Clipperton Island. Length 1.18 mm.

One minute, glassy shell found in shell washings closely resembles *Amphithalamus trosti*. It differs from the type specimen of that species in that the whorls are slightly more rounded and impressed at the suture. Only a faint trace of a peripheral threadlet is present but this feature apparently varies somewhat in a series of specimens from the type locality of *A. trosti*. The similarity of the present specimen to the Panamanian shell is so great that we assign it to that species.

Heliacus infundibuliformis strigatus (Hanley).

(Figure 3.)

Solarium infundibuliforme variety (?) *strigata* Hanley, Thes. Conch., vol. 3, *Solarium*, p. 243, pl. 254, (*Solarium*, pl. 5), fig. 94, 1863. Expl. to pl. 5, "Sandwich Isles (var. *Chemnitzii*)."

Not *Solarium chemnitzii* Kiener, Spéc. Gen. et Icon. Coq. Viv., Fam. Turbinacées, *Solarium,* p. 12, pl. 4, fig. 8, 1838–1839. "Habite la mer des Indes l'île Bourbon et la mer de la Chine." According to Tryon, 1887 this = *Trochus infundibuliformis* Gmelin, Linnaeus Syst. Nat., Tom. 1, Pars. 6, p. 3575, 1791. "Habitat rarissimus. . ." (Ref. to Chemnitz, Bd. 5, pl. 173, figs. 1706, 1707, 1781. "Ihr Vaterland ist mir unbekannt.")

Torinia infundibuliforme Gmelin var. *strigata* Hanley, Tryon, Man. Conch., vol. 9, p. 20, pl. 6, fig. 99, 1887. (No locality cited.)

Heliacus infundibulum strigata Hanley, Hertlein and Allison, The Veliger, vol. 9, no. 2, p. 140, 1966. Clipperton Island.

A specimen from Locality B-4237 (A-588-1), beach on Clipperton Island, 9.5 mm. in maximum diameter and 5.5 mm. high, appears to be referable to the form described by Hanley as "*Solarium infundibuliforme* variety (?) *strigata.*" No specific locality was assigned to this variety but localities cited for *S. infundibuliforme* were, "Philippines; Lord Hood's Island; Sandwich Isles (var. *Chemnitzii*)."

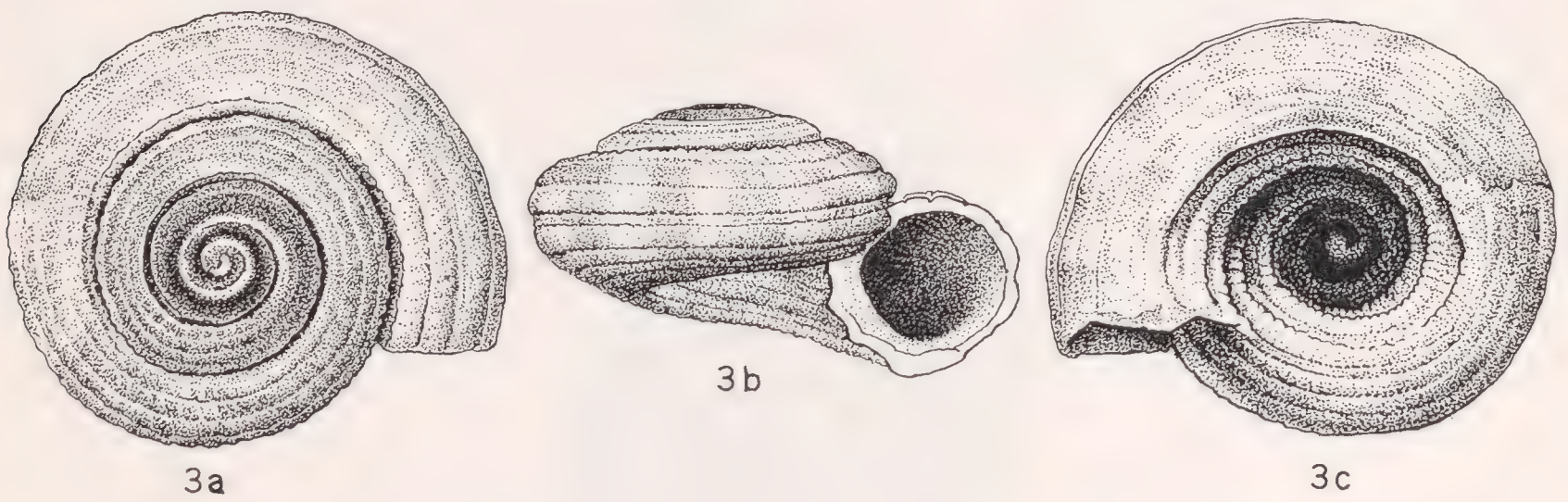


Figure 3. *Heliacus infundibuliformis strigatus* (Hanley). Hypotype no. 37123 (UC), from beach on Clipperton Island. 3a, apical view; 3b, apertural view; 3c, basal view; maximum diameter 9.5 mm.

Hanley's original description follows: "In the variety (?) *strigata* (f. 94) there are 3 approximate narrower, and 3 broader belts under the lower peripheral one: the threads, if any, are most minute: there are 4 or 5 ridges on the umbilical wall." The coloration was mentioned by Tryon as, "Periphery and the rib below it ornamented with white and smoky-brown spots."

The present specimen from Clipperton Island agrees so well with the variety described by Hanley that we refer it to that form.

The form described as *Solarium chemnitzii* by Kiener was reported from Hawaii by Hanley. Later, Tryon relegated Kiener's species to the synonymy of the earlier "*Trochus*" *infundibuliformis* Gmelin and considered Hanley's "*Solarium infundibuliforme* var. (?) *strigata*" to be a valid variety. Tryon also suggested the possibility that Gmelin's species might be identical with the earlier *Turbo crenellus* Linnaeus, 1767, and later Bayer (1944) also followed this assignment. Neither *H. infundibuliformis* nor *H. i. strigatus* was reported from Hawaii

in recent papers by Bryan (1958, suppl. p. 5) nor by Robertson (1967, p. 247). However, Dr. Alison Kay informed us (written communication, 5 November 1967) that one shell referable to *H. infundibuliformis* was dredged (by the *Pele*) off Oahu in 40 fathoms.

Odostomia (Chrysallida) limbaughi Hertlein and Allison, new species.

(Figure 4.)

DESCRIPTION. Shell minute, ovately conic, vitreous. Nuclear whorl about half immersed at a right angle in the succeeding post-nuclear whorl, and bearing 5 spiral lirations. First and second post-nuclear whorls straight sided, slightly shouldered at the summit and sculptured with a row of nodules of which about 18 are present on the penultimate whorl. Spiral sculpture consists of flattened ribs which are separated by incised spiral grooves, the first post-nuclear whorl with 4, the second 6, the penultimate with 8 and the body whorl with 8 of which the last 4 are narrower. The periphery and base of the last whorl is well rounded. The aperture is large, broadly ovate, and angulated posteriorly; outer lip thin, the base slightly reflected. Length 1.47 mm., maximum diameter .72 mm.

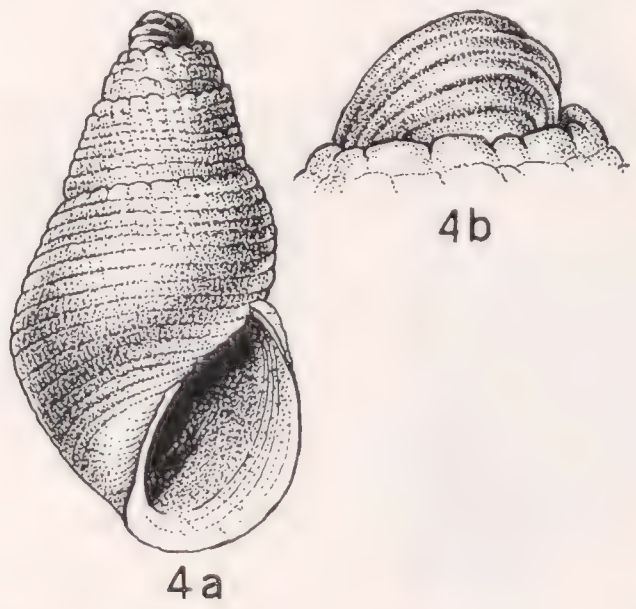


FIGURE 4. *Odostomia (Chrysallida) limbaughi* Hertlein and Allison, new species. Holotype no. 37124 (UC), from Clipperton Island. 4a, apertural view; length 1.47 mm.; 4b, view of nuclear whorl, greatly enlarged.

HOLOTYPE no. 37124, University of California Museum of Paleontology, Invertebrate Type Collection, from Locality B-4241, outer portion of intertidal bench with prominent *Pocillopora*, brown algae, and slight coralline algae, Clipperton Island. E. C. Allison, collector.

This new species is quite different from any species known to us. It bears a general resemblance to *Odostomia (Chrysallida) sapia* Dall and Bartsch (1909, p. 167, pl. 18, figs. 3, 3a) described from San Diego, California. The new species differs from *O. (C.) sapia* in that the two post-nuclear whorls are straight sided rather than rounded and these are sculptured with more numerous spiral ribs.

This species is named for Conrad Limbaugh, leader of the Expedition to Clipperton Island during which the type specimen was collected.

Turbonilla (Pyrgisculus) clippertonensis Hertlein and Allison, new species.
(Figure 5.)

Description. Shell elongated, nuclear whorls about one and a half, smooth, the nucleus about one-half immersed, the axis at almost a right angle to that of the succeeding whorls; post-nuclear whorls 4, decidedly rounded and constricted at the sutures, sculpture consisting of about 16 slightly curved axial riblets on the first whorl and 18 or 20 on the following whorls; axial sculpture crossed by spiral threads of nearly the same strength as the axials, a fine node is formed at the intersection of the axial and spiral sculpture; the intercostal spaces each with a slightly spirally elongated pit, forming spiral series; base of last whorl sculptured with fine spiral lines; aperture ovate, the anterior portion very broadly rounded. Length 1.1 mm., maximum diameter .43 mm.

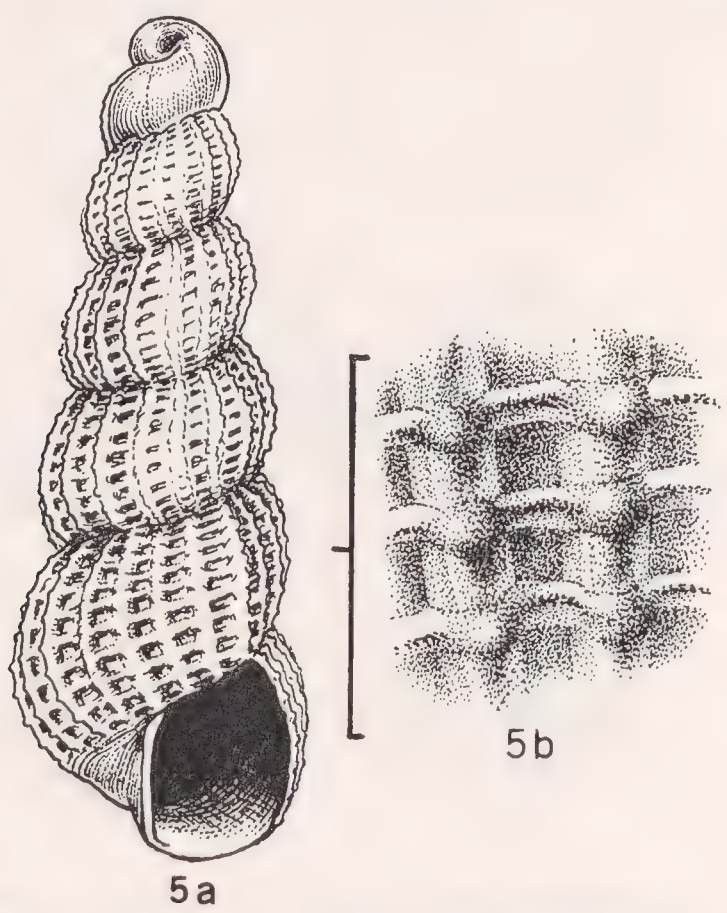


Figure 5. *Turbonilla (Pyrgisculus) clippertonensis* Hertlein and Allison, new species. Holotype no. 37125 (UC), from Clipperton Island. 5a, apertural view; length 1.1 mm.; 5b, detail of sculpture greatly enlarged.

Holotype. University of California Museum of Paleontology, Invertebrate Type Collection, no. 37125, from Locality B-4241, Clipperton Island.

Remarks. This new species is provisionally placed in the subgenus *Pyrgisculus* Monterosato because of its general similarity to the species described as *Dunkeria paucilirata* Carpenter, a species placed in *Pyrgisculus* by later authors. The general shape of the rounded whorls, strongly constricted at the suture, and the strong axial riblets, are similar to those features on that species.

The shell of the new species differs decidedly from the species described by Carpenter in the more closely spaced axial riblets, in that the spiral threads are nearly as strong as the axials and in that pits are present in the intercostal spaces.

The strong spiral sculpture on the present species is similar to that of some species of *Pyrgiscus* Philippi.

Dunkeria paucilirata Carpenter (1856, p. 534) was described from a single specimen from "Mazatlan; 1 sp. off *Chama*," Mexico. It was illustrated later under the name of *Turbonilla (Pyrgisculus) paucilirata* (Carpenter) by Dall and Bartsch (1909, p. 129, pl. 12, fig. 10) and more recently as *Chemnitzia (Dunkeria) paucilirata* (Carpenter) by Brann (1966, p. 72, pl. 47, fig. 536). The spiral sculpture of that species is much finer than the axial and no pits are visible in the intercostal spaces shown in the illustrations.

Colubraria ochsneri Hertlein and Allison, new species.

(Figures 6, 7, 8.)

Colubraria species, Hertlein and Allison, The Veliger, vol. 9, no. 2, p. 140, 1966.

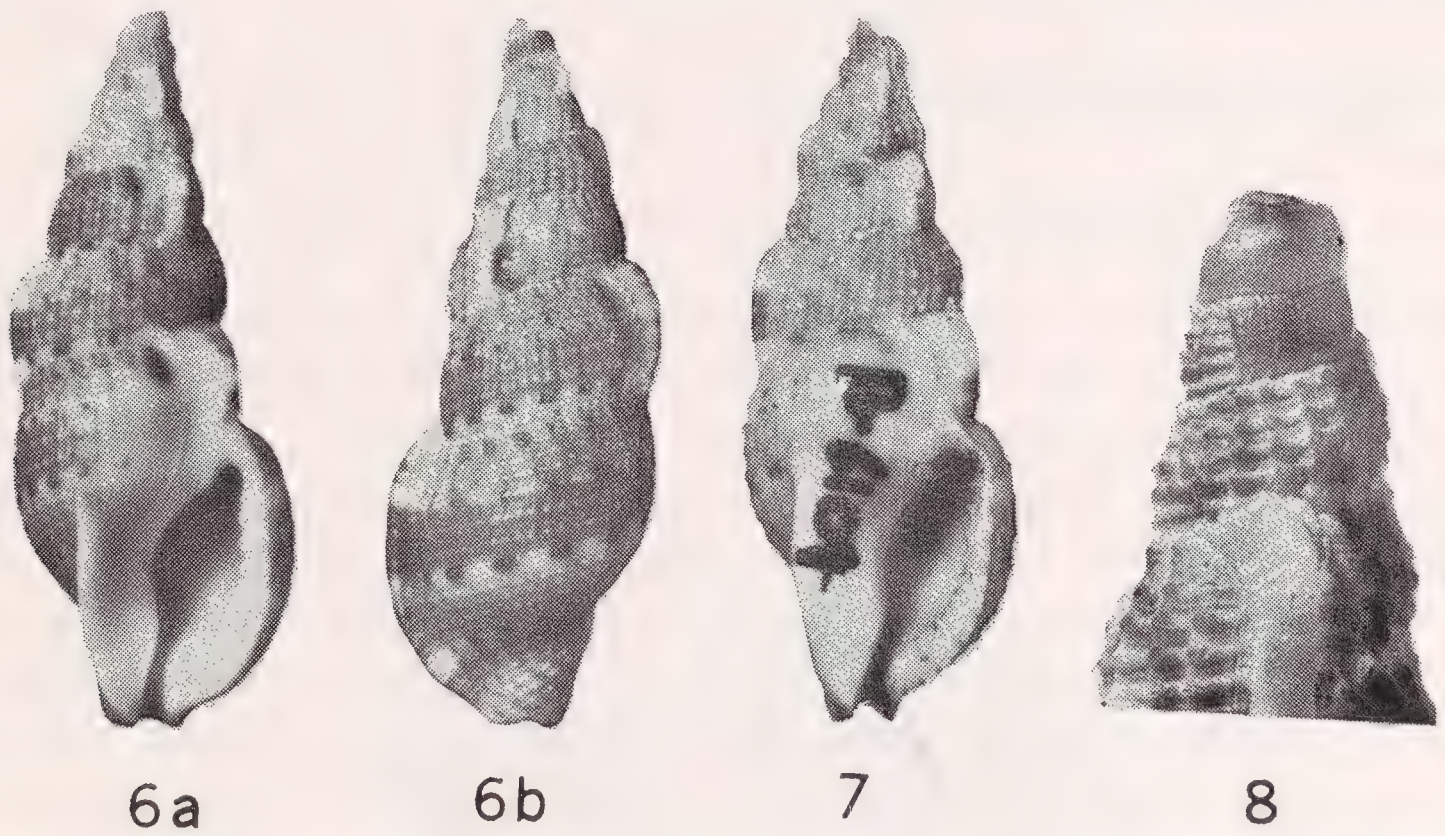
Description. Shell elongately turreted, of medium thickness, about six and a half gently convex whorls, each with a prominent varix, the varices on every other whorl are rudely aligned in apertural view; protoconch and nuclear whorls lacking on holotype; about 12 well developed, closely and evenly spaced radial threads appear on the fourth whorl and these increase to about 28 or 30 on the last whorl, these are crossed by concentric threads, about five on the fourth whorl and seven or eight on the penultimate whorl, a double row is present anterior to the suture on the last whorl and these are followed by about 20 or more, evenly spaced but somewhat finer toward the base; a node is present where the radial and concentric threads cross, the whole forming granular, reticulate sculpture; the interspaces between the radials and between the concentric threads are ornamented with a few minute concentric striae, about six on the body whorl, separated by narrower grooves parallel to the major threads; aperture elongately oval, posteriorly ending in a narrow notch in the parietal callus; outer lip with a varix, the inner margin with fine, paired striae, the pillar excavated in the middle, the inner lip formed by a broad, smooth, white callus which at base projects outward as a narrow plate; the anterior canal is rather narrow, slightly recurved; color of shell light brown with a darker medial concentric band, above and below which on the body whorl there is a row of small brown spots, the varices are light in color but with brown spots sometimes corresponding to the brown bands. Dimensions of the holotype: length (apex lacking), 29.8 mm., maximum diameter, 11.4 mm.

The protoconch of a paratype, 23.2 mm. in length, is slightly convex, brown, followed by 2 smooth, glassy whorls, the latter one developing very fine longitudinal threadlets which are crossed by concentric threadlets forming decussate sculpture, with very fine beads at their intersections. In general appearance, these features resemble those of *Colubraria jordani* Strong illustrated by Campbell (1961, fig. 1).

Holotype, no. 37126 and paratypes 37127, 37129, University of California

Museum of Paleontology, Invertebrate Type Collection, from Locality B-4237 (A-588-1, Allison field station number), beach at Clipperton Island. A paratype, no. 37128 from Locality B-6101 (A-588-5), approximately 100 meters off edge of reef flat and 30 meters inshore from outer edge of submerged terrace (depth, 10–12 meters) opposite United States Naval Observatory marker on north side of island.

Paratypes also are in the California Academy of Sciences, Department of Geology, Type Collection.



Figures 6, 7, 8. *Colubraria ochsneri* Hertlein and Allison, new species. From Clipperton Island. 6, Holotype no. 37126 (UC), length (apex lacking) 29.8 mm.; 6a, apertural view; 6b, dorsal view. 7, paratype no. 37127 (UC), length (apex lacking) 27.3 mm., apertural view. 8, paratype no. 37129 (UC), view of apical whorls approximately × 19.

Remarks. About 25 specimens of this new species, 12 to 30.5 mm. long (apex lacking on most specimens) have been available for study. There is some variation in the degree of coarseness of the granular sculpture on various specimens but this may be the result of erosion.

The general form and sculpture of this new species is similar to that of *Triton nitidulus* Sowerby (1833, p. 71; Reeve, 1844, *Triton*, species 70, pl. 17, fig. 70), originally described from "Hab. ad Insulam Annaa," "Found on the reefs. - G.B.S." The new species differs from *Colubraria nitidula* in the smaller size, less elongate form, shorter anterior canal and proportionately wider aperture.

Colubraria ochsneri, new species, appears to be distinct from any species of *Colubraria* described from the eastern Pacific (see Campbell, 1961). The exterior of the shell of the new species bears finer sculpture than the "narrow form" of *C. lucasensis* Strong and Hertlein from the Galápagos illustrated by Emerson and D'Attilio (1966, p. 176, pl. 26, figs. 1–4) and the anterior canal is slightly shorter. A difference in detail of sculpture is that on *C. ochsneri*, new species,

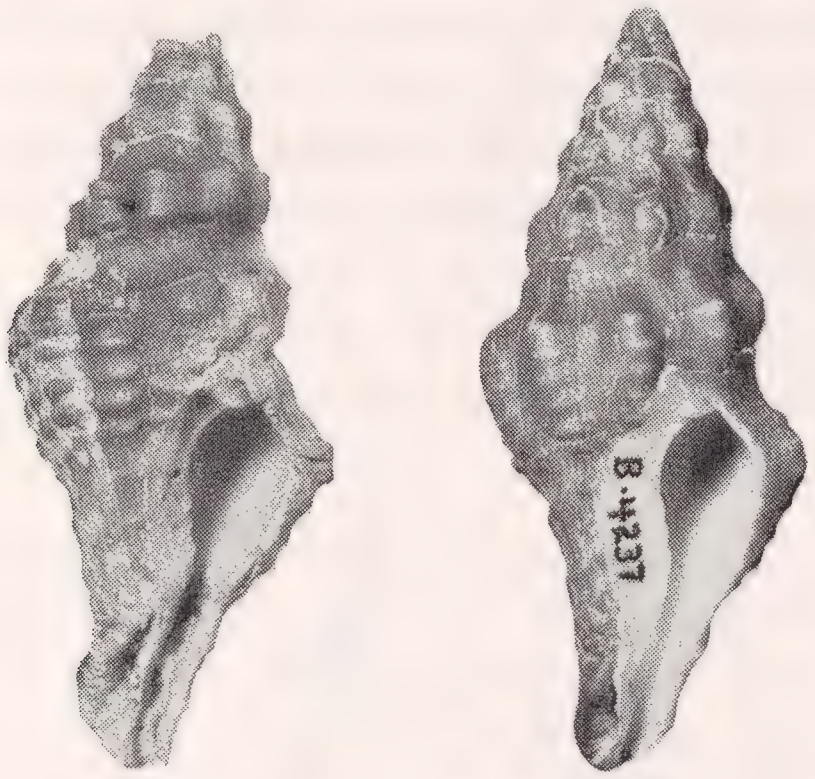
the interspaces between the node-bearing concentric spirals are sculptured with fine spiral striae of nearly equal size whereas on *C. lucasensis* the corresponding spiral striae are somewhat coarser and among them one thread is coarser than the others.

This species is named for Washington Henry Ochsner who collected marine shells on Clipperton Island in 1905 during the Expedition of the California Academy of Sciences to the Galápagos Islands.

Latirus clippertonensis Hertlein and Allison, new species.

(Figures 9, 10.)

Latirus aff. *L. socorroensis* Hertlein and Strong, Hertlein and Allison, The Veliger, vol. 9, no. 2, p. 140, 1966.



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Figures 9 and 10. *Latirus clippertonensis* Hertlein and Allison, new species. 9, holotype no. 37130 (UC), from Clipperton Island. Length (apex lacking) 50.5 mm.; 10, paratype no. 37131 (UC), length 42.8 mm.

Description. Shell elongately turreted, yellowish-white covered with a golden-orange periostracum; 5½ whorls present, the apex lacking; whorls regularly increasing in size, concave above a subangulate shoulder, below this gently convex, the last whorl nearly straight sided and sloping steeply anteriorly; axial sculpture consists of 9 rounded ribs on the penultimate whorl and 10 on the last whorl, these fade out toward the base on the last whorl; spiral sculpture on the early whorls consists of 2 raised cords, 3 on the penultimate whorl and 6 on the last whorl, followed by 3 or 4 widely spaced ones on the canal; the spiral cords are faint in the interspaces but where they cross the radial ribs they form elongated nodes, very prominent on the shoulder; aperture ovately elongate, inner margin of outer lip with fine spiral ridges, a calcareous node on the parietal wall near the posterior end of the aperture, columella with 3 plaits near the

lower end, canal narrow; siphonal fasciole well developed. Dimensions of holotype: length (apex lacking) 50.5 mm., maximum diameter, 23.5 mm.

Holotype no. 37130, University of California Museum of Paleontology, Invertebrate Type Collection, from Locality B-6120 (A-588-25, Allison field station number), off edge of submerged terrace at a depth of 40–45 meters, on the north side of Clipperton Island opposite the west end of main washout area. A paratype no. 37131 and two additional imperfect specimens, from Locality B-4237 (A-588-1, Allison field station number), shells washed onto the beach, Clipperton Island.

Remarks. This form, as is true of a number of species and subspecies described from Clipperton Island, although resembling its nearest congener, develops shell characters differing sufficiently to separate it from the typical form. The present specimens are quite similar to some forms of *Latirus socorroensis* Hertlein and Strong (1951, p. 76, pl. 26, fig. 8), from Clarion and Socorro islands, Revillagigedo islands, Mexico, but they differ especially in their more elongate outline, longer and wider anterior canal and coarser spiral ribbing which is more sharply nodulose posteriorly.

Succinea atollica Hertlein and Allison, new species.

(Figure 11.)

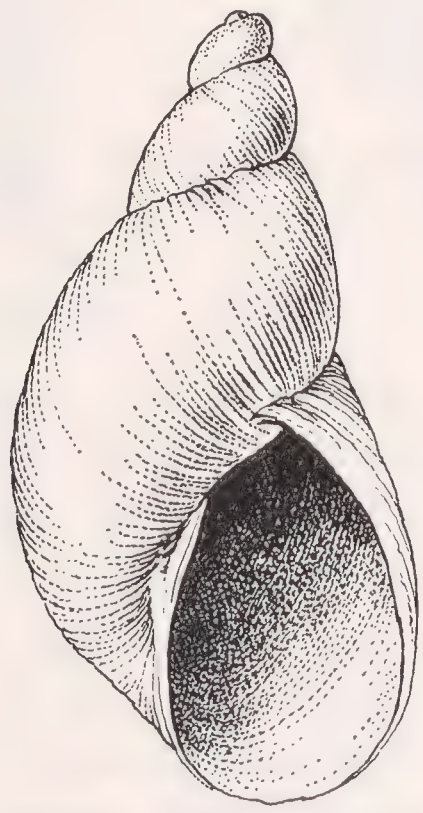

Figure 11. *Succinea atollica* Hertlein and Allison, new species. Holotype no. 37132 (UC), from Clipperton Island. Length 11.1 mm.

Description. Shell elongately ovate, thin, translucent, upper whorls light amber colored, the last whorl grayish-yellow with irregularly spaced brown lines paralleling the lines of growth; spire acute, about one-half or slightly less the total length of the shell; whorls 4½, broadly convex, sculptured only with lines of growth and on the last whorl there are shallow longitudinal depressions parallel

to the lines of growth; suture rather deeply incised; columella with well developed callus which is appressed and decidedly reflected in the middle but becoming thinner and gradually disappearing before reaching the base of the inner lip; aperture elongately ovate about ½ (or slightly more) the length of the shell, the greatest expansion before reaching the anterior margin. Length of shell 11.1 mm., maximum diameter 5.76 mm., length of aperture 6.47 mm., width of aperture 3.72 mm.

Holotype no. 37132, and paratypes nos. 37133, 37134, 37135, University of California Museum of Paleontology, Invertebrate Type Collection, from Locality B-4241 Clipperton Island. Paratypes also in the California Academy of Sciences, Department of Geology, Type Collection.

Remarks. About 30 well-preserved specimens from Locality B-4241, also many weathered specimens from Locality 4237, beach, Clipperton Island.

The new species described here bears a close resemblance to the form described as *Succinea luteola* var. *subtilis* von Martens (1898, p. 331, pl. 19, fig. 2) from Vera Cruz, Mexico. It differs from the east Mexican form in the slightly more slender outline, in the narrower body whorl, and in that the aperture is about one-half rather than five-ninths the length of the shell.

Opeas oparanum (Pfeiffer).

(Figure 12.)

Bulimus oparanus Pfeiffer, Proc. Zool. Soc. London for 1846, p. 34, issued May, 1846. "From the island of Oparu; found in earth at roots of Plants (H. Cuming, Esq.)."

Opeas oparanum (Pfeiffer), Pilsbry, Man. Conch., ser. 2, vol. 18, p. 183, pl. 22, figs. 1, 2, 3, 12; pl. 24, fig. 39, 1906. "Hawaii, Marquesas, Paumotu, Society." Bartsch and Rehder, Smithson. Miscell. Coll., vol. 98, no. 10 (Pub. 3535), p. 16, 1939. Clipperton Island. Hertlein and Allison, The Veliger, vol. 9, no. 2, p. 140, 1966. Clipperton Island.

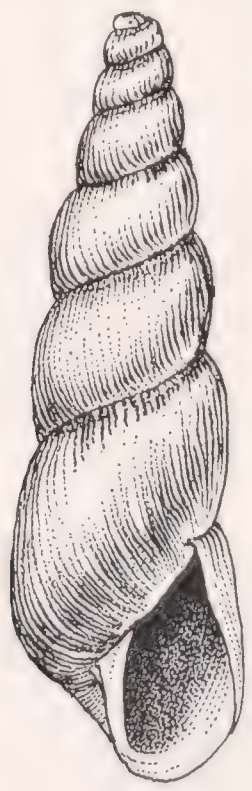

Figure 12. *Opeas oparanum* (Pfeiffer). Hypotype no. 37136 (UC), from Clipperton Island. Length 9.3 mm.

Many specimens of *Opeas oparanum* were taken on Clipperton Island, where they were living commonly in the protection of rock and plant debris. This species is rather widely distributed in the Polynesian region.

?Omalogyra species.
(Figure 13.)

A few minute, flatly coiled, translucent brown shells of gastropods, some bearing microscopic threadlets on the periphery, are present in shell washings from Clipperton Island. These were taken on "the outer portion of the intertidal bench with prominent *Pocillopora*, brown algae, and slight coralline algae."

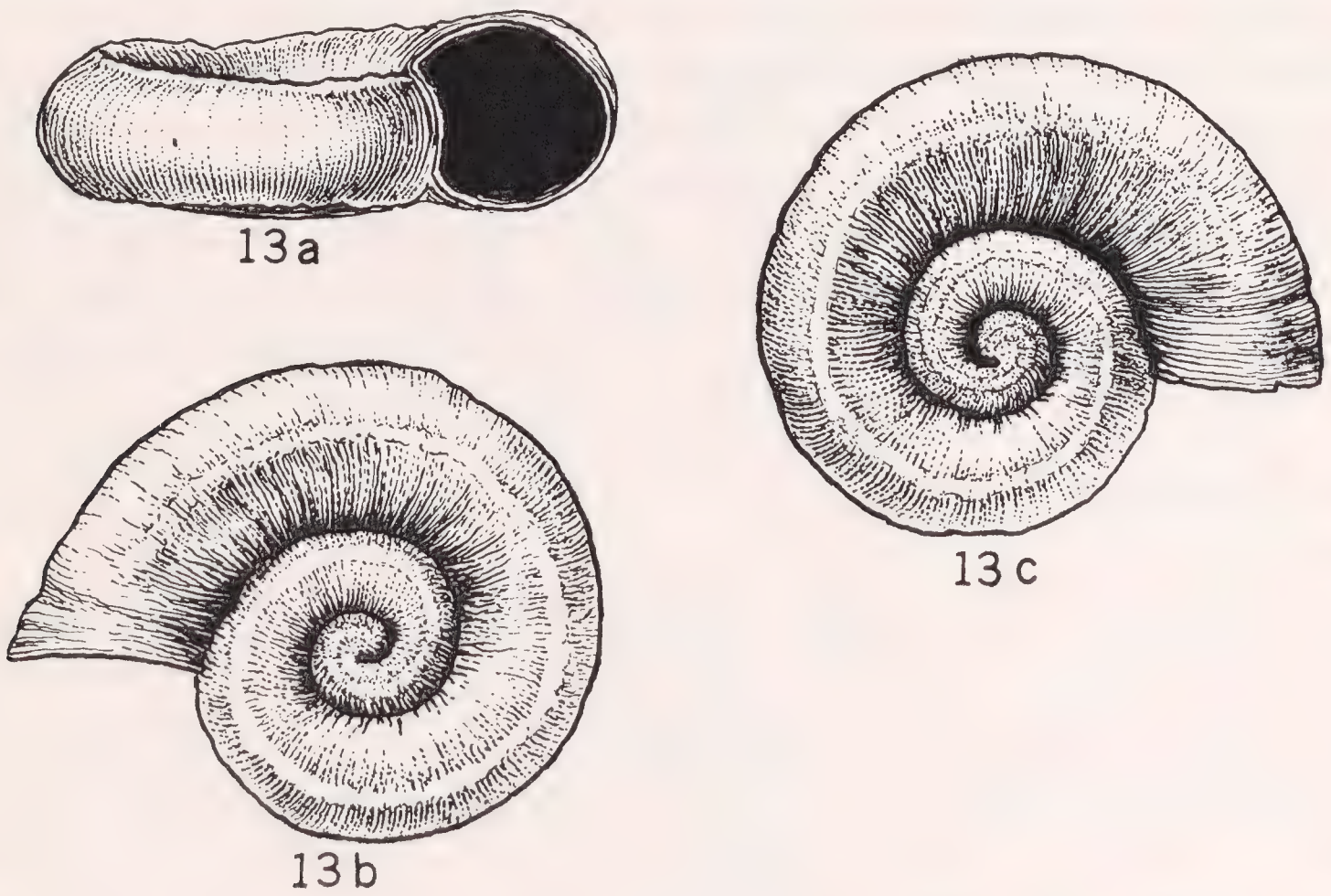

Figure 13. *?Omalogyra* species. Hypotype no. 37137 (UC), from Clipperton Island. Maximum diameter 0.425 mm., height 0.18 mm. 13a, apertural view; 13b, basal view; 13c, apical view.

These specimens were examined by Allyn G. Smith who pointed out their similarity in general appearance to some families of land snails such as the Endodontidae. However, in view of the locality, the lack of soft parts and the operculum, he agreed that these shells may be referred questionably to *?Omalogyra* Jeffreys, a genus of minute marine snails.

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No. 67, 8 pages, 3 figures. June 27, 1968

Fish Remains from Two Submerged Deposits in Tomales Bay, Marin County, California

By

W. I. Follett

California Academy of Sciences, San Francisco 94118

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Introduction

This is a report on the fish remains collected in 1964 by Calvin Crowell Daetwyler, Jr., then of the Scripps Institution of Oceanography, from two submerged deposits (designated Test Boring No. 1 and Test Boring No. 3), in Tomales Bay, Marin County, California.

Test Boring No. 1 was near the middle of White Gulch, at 38°11′40.5″ N. lat., 122°56′05.5″ W. long. (see USC&GS Chart 5603), where the water is 7 feet deep at mean lower low water. White Gulch is on the southwest shore of Tomales Bay, nearly opposite Hog Island. The specimens were collected at a depth of 10.7 to about 12.1 feet below mean lower low water (therefore 3.7 to about 5.1 feet below the surface of the bay bottom). Here the top 3 feet of the sediment consists of black silty clay, which is probably due to erosion during the historic agricultural period. Below this clay, the bottom material is sandier, and contains a considerable amount of shell resembling midden shell. Mixed with this material are small pieces of charcoal. At 12.1 feet a small shell bead was found. Material from this locality, regarded by James R. Moriarty as definitely archaeological, yielded a radiocarbon date (LJ-GAP-43) of 340 ± 130 years before the present (Hubbs and Bien, 1967, p. 266). The date confirmed other evidence indicating very recent tectonic subsidence.

Test Boring No. 3 was off Manila Marina, approximately 1300 feet from the northeast shore of Tomales Bay, at 38°10′47.5″ N. lat., 122°54′54″ W. long., where the water is 16 feet deep at mean lower low water. Manila Marina (not shown on the chart) is 0.3 mile generally southeast from Blake Landing, and

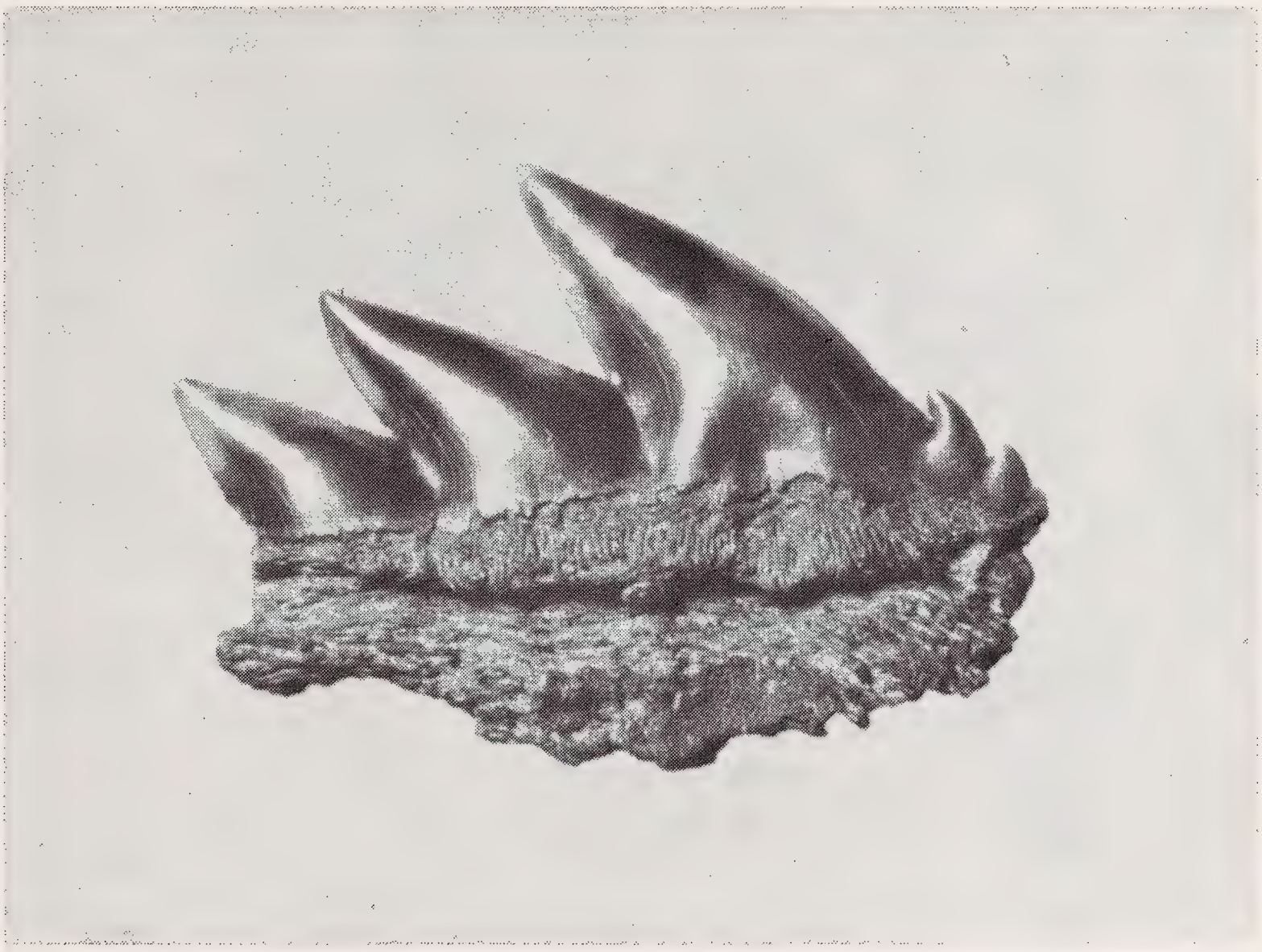

FIGURE 1. Lower tooth, length of base 14 mm., of sevengill shark (*Notorynchus maculatus*); representing a shark about 190 cm. in total length; from Test Boring No. 3.

2.6 miles (by road) generally northwest from the Marshall Post Office. The specimens were collected at a depth of 21.0 to 24.5 feet below mean lower low water (therefore 5.0 to 8.4 feet below the surface of the bay bottom). There was no indication of a midden at this locality. Material from this locality yielded a radiocarbon date (LJ-GAP-46) of 1700 ± 190 years before the present (Hubbs and Bien, 1967, p. 267). Dr. Daetwyler commented, in the report just cited, that the shelly pebble horizon correlates with a horizon widespread in the bay, and may represent a lower relative sea stand, related to suspected tectonic submergence along an active fault zone.

Further details of these test borings were noted by Daetwyler (1965, pp. 173–175).

The specimens are deposited in the marine-geological collections at the Scripps Institution of Oceanography, La Jolla, California.

Fishes Represented

The collection comprises 26 fish remains, all of which are incomplete or fragmentary. Six species, referable to six genera and five families, are represented, as follows:

Family Hexanchidae. Cow Sharks

Notorynchus maculatus Ayres, 1855. Sevengill shark.

This palatable shark (see Roedel and Ripley, 1950, fig. 24), which has been said to attain a total length of about 300 cm. (Garrick and Schultz, 1963, p. 58), is known to enter Tomales Bay, at times in considerable numbers.

Material. One *lower tooth* (incomplete; fig. 1), representing a shark about 190 cm. in total length, from Test Boring No. 3. (See Roedel and Ripley, 1950, fig. 25, for a drawing of a lower tooth of this species.) This specimen was mentioned by Daetwyler (1965, p. 175).

Family Myliobatididae. Eagle Rays

Myliobatis californica Gill, 1865. Bat stingray.

This edible stingray (see Roedel and Ripley, 1950, fig. 61, as *Holorhinus californicus*), which attains a weight of 95 kg. (Baxter, 1960, p. 19) was described, as *Rhinoptera vespertilio*, by Girard (1856, p. 137; 1857, p. 544, pl. 26), from Tomales Bay, where the species is exceedingly abundant.

Material. One *centrum* (incomplete), possibly representing a half-grown individual, from Test Boring No. 1.

Family Clupeidae. Herrings

Clupea pallasii Valenciennes *in* Cuvier and Valenciennes, 1847. Pacific herring.

This important food fish (see Roedel, 1953, fig. 32), which has been said to attain a total length of about 45 cm. (Roedel, 1953, p. 34), enters Tomales Bay to spawn, especially during January, February, and March (Scofield, 1952, p. 499).

Material. Eight *vertebrae* (incomplete or fragmentary), representing one or more fish about 21 cm. in total length, from Test Boring No. 1. (Characters differentiating the vertebrae of the herring from those of the sardine were discussed by Chapman, 1944, pp. 14–16.)

Sardinops sagax (Jenyns, 1842). Pacific sardine.

This excellent food fish (see Roedel, 1953, fig. 31, as *Sardinops caerulea*), which usually does not exceed 33 cm. in total length (Roedel, 1953, p. 33), at times enters Tomales Bay.

Material. One *right dentary* (incomplete; fig. 2), 7 *scales* (incomplete), and 5 *vertebrae* (incomplete), representing one or more fish about 25 cm. in total length, all from Test Boring No. 1; and 1 *scale* (incomplete), from Test Boring No. 3. (See Phillips, 1942, figs. 9, 12–17, and 22, for drawings of dentary, vertebrae, and scales.)

Figure 2. Right dentary, length 12 mm., of Pacific sardine (*Sardinops sagax*); representing a fish about 25 cm. in total length; from Test Boring No. 1.

(It is perhaps not generally known that despite the great decline of the population of this species in California waters, small numbers still persist in Tomales Bay. According to Frank Spenger, Sr., a few large sardines are seined in that bay each year during the early spring. The most recent record of this species from Tomales Bay that I have verified is that of a large adult seined by Frank Spenger, Sr., and Paul R. Needham on 26 April 1964, at Young Landing, lat. 38°09′ N., long. 122°54′ W.)

Family Merlucciidae.[1] Hakes

Merluccius productus (Ayres, 1855). Pacific hake.

This fish (see Roedel, 1953, fig. 45), which attains a total length of about 90 cm., is said to be generally rejected as food by the white man, because of its soft flesh and poor keeping qualities (Roedel, 1953, p. 48), although it has been said to be "a fine food fish if kept cool and damp" (Cannon, 1964, p. 214). I have not found this species reported from Tomales Bay. It occurs principally at depths greater than 50 fathoms (Best, 1963, p. 54).

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[1] I follow Marshall (1966, p. 279) in recognizing the family Merlucciidae.

FIGURE 3. Precaudal vertebra, length 6 mm., of Pacific hake (*Merluccius productus*); representing a fish about 50 cm. in total length; from Test Boring No. 1.

MATERIAL. One *precaudal vertebra* (incomplete; fig. 3), representing a fish about 50 cm. in total length, from Test Boring No. 1. (See Radcliffe, 1913, pl. 15, for a photograph of the precaudal vertebrae of this species.)

Family PLEURONECTIDAE. Righteyed Flounders

?Platichthys stellatus rugosus Girard, 1854. Southern starry flounder.

This good food fish (see Roedel, 1953, fig. 63) averages about 41 cm. in total length and about 1 kg. in weight (Baxter, 1960, p. 26), although reports published during the nineteenth century indicated that it attained a much larger size (Follett, 1957, p. 68). It is common in Tomales Bay.

MATERIAL. One *vertebra* (fragment; questionably referred to this species), possibly representing a small adult, from Test Boring No. 1.

DISCUSSION

The shark tooth and one sardine scale were taken from the deposit (probably natural) sampled by Test Boring No. 3. The material of all other species, and most of the sardine material, came from the midden deposit sampled by Test Boring No. 1.

With the exception of the hake, all species represented in the midden collection were presumably taken commonly by aborigines in comparatively shallow water in Tomales Bay. The herring and sardine could well have been taken by a seine or a gill net; the stingray and flounder, by a hand line cast from a favorable position on the shore.

The presence of an element of the hake is not convincing evidence of the use of watercraft by the aborigines who may have collected these fishes. Although the hake normally occurs in oceanic waters at depths greater than 50 fathoms (Best, 1963, p. 54), its known tendency to pursue its prey into shallow water, on occasion—even to the extent of stranding itself (De Witt, 1952, p. 438)—suggests that it may sometimes enter Tomales Bay. The specimen represented may therefore have been taken by seine or gill net or by hook and line in Tomales Bay, or may have been found stranded, perhaps at one of the beaches near the mouth of the bay.

At least three of the species represented are known to have been utilized by aborigines elsewhere in California: the bat stingray, at the Burton Mound, Santa Barbara County (Harrington, 1928, p. 135, as eagle ray), at the Conejo Rock Shelter, Ventura County (Follett, 1965, p. 83), at one of the Irvine sites on Newport Bay, Orange County (Follett, 1966, p. 190), and at a number of other sites (see Follett, 1964, p. 34); the Pacific sardine, at the Conejo Rock Shelter (Follett, 1965, p. 83); and the southern starry flounder, at Strawberry Point, San Francisco Bay (Follett, 1957, p. 69), and at Estero de Limantour, Marin County (Follett, 1964, p. 32).

Teeth of the sevengill shark were recorded from a Pleistocene deposit at Playa del Rey, Los Angeles County, California (Kanakoff, 1956, p. 48; Fitch, 1964, pp. 7–8, fig. 1), and from Lower Pleistocene deposits at Capistrano Beach Palisades, Orange County (Kanakoff, 1956, p. 48), and at San Pedro, Los Angeles County (Fitch, 1967, p. 3); tooth segments of the bat stingray, from an Upper Pleistocene deposit at Newport Bay Mesa, Orange County (Kanakoff, 1956, p. 48), from a Pleistocene deposit at Playa del Rey (Kanakoff, 1956, p. 48; Fitch, 1964, p. 13, fig. 12, and 1966, pp. 4, 7), from a Lower Pleistocene deposit at San Pedro (Fitch, 1967, p. 8), and from a Pliocene deposit at Long Beach, Los Angeles County (Kanakoff, 1956, p. 48; Fitch and Reimer, 1967, pp. 80–81); otoliths of the Pacific herring, from a Lower Pleistocene deposit at San Pedro (Fitch, 1967, p. 9, fig. 1); and otoliths of the Pacific hake, from a Pleistocene deposit at Playa del Rey (Kanakoff, 1956, p. 48; Fitch, 1964, p. 14, fig. 14, and 1966, pp. 4, 10) and from a Pliocene deposit at Long Beach (Fitch and Reimer, 1967, p. 82, fig. 12).

Acknowledgments

I wish to express my appreciation to Dr. Carl L. Hubbs of the Scripps Institution of Oceanography, for the opportunity to report on this collection

and for assistance and advice; to Mrs. Lillian J. Dempster of the California Academy of Sciences, for assistance with the manuscript; and to Mr. Maurice C. Giles of the California Academy of Sciences, for enlargements of the photographs.

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No. 68, pp. 1–24, 13 figures, 5 tables. September 25, 1968

Scorpions from Northern Mexico: Five New Species of *Vejovis* from Coahuila, Mexico

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OCCASIONAL PAPERS
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CALIFORNIA ACADEMY OF SCIENCES

No. 68, pp. 1–24, 13 figures, 5 tables. September 25, 1968

Scorpions from Northern Mexico: Five New Species of *Vejovis* from Coahuila, Mexico

By

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ABSTRACT: Five new species of scorpions, *Vejovis gilvus, Vejovis pallidus, Vejovis cazieri, Vejovis coahuilae,* and *Vejovis minckleyi* were collected in the Cuatro Cienegas basin of Coahuila, Mexico and are here described. Only one of these species, *Vejovis coahuilae*, is known from outside of the small intermontane Cuatro Cienegas basin.

INTRODUCTION

The purpose of this paper is to describe and name five new species of scorpions belonging to the genus *Vejovis*, from the Cuatro Cienegas basin of Coahuila, Mexico. The descriptions of these five species are based on 227 specimens collected between the years 1965 and 1967. In addition to these, other specimens representing three genera and three families were collected. These, however, will not be discussed in this paper because adequate material is not available at this time. It appears that the Cuatro Cienegas basin may very well have one of the richest scorpion faunas in North America.

The measurements of specimens given in this paper are generally the standard ones used in scorpion systematics. Measurements were taken with the use of a microscope equipped with a calibrated eyepiece micrometer. The total body length is the sum of the lengths of the carapace, mesosoma, metasoma, and telson. Carapace length was taken along a plane tangent to the lateral margin of the ocular tubercule. The mesosoma length was measured along the dorsal median plane. The metasoma length is the sum of the separate lengths of each segment measured dorsally. Telson length is the sum of vesicle and aculeus

lengths. The middle lamellae counts refer only to the number of subcircular sclerites forming a single distinct row. An index of hirsutness is given by indicating the number of large reddish hairs on each of several body parts (namely, inferior keels of metasoma, vesicle, fulcra and middle lamellae).

Acknowledgments

Sincere thanks and appreciation to Wendell L. Minckley who has stimulated so much interest in the little known, yet fascinating Cuatro Cienegas basin; to Wendell L. Minckley, Charles O. Minckley, Walter K. Taylor, William S. Parker, Les E. Cullum, Robert Winokur, and Jose Lugo, Jr. for collecting many of the specimens used in this study; and to William S. Brown and Modesto de la Garza P. for assistance in the field. Thanks are also due to Charlene F. Williams for clerical assistance.

The Cuatro Cienegas Area

Cuatro Cienegas is a small, horseshoe-shaped valley approximately 40 × 30 kilometers, enclosed by ranges of the Sierra Madre Oriental in central Coahuila, Mexico. It gets its name from a small agricultural town called Cuatro Cienegas de Carranza (in this paper referred to as Cuatro Cienegas). The rugged mountains are steep, bare, and composed of Cretaceous limestone. The valley lies at an elevation of about 700 to 750 meters above sea level, has a vegetation of the Chihuahuan desert type, and is noted to biologists for its interesting and varied aquatic habitats and drainages. Several completely internal drainage systems occur as well as an external drainage toward the Rio Grande. The area has recently received distinction because of its rich snail and fish faunas which contain many endemic species.

New Species

Vejovis gilvus Williams, new species.
(Figures 1, 2.)

Diagnosis. This small to moderate sized species of *Vejovis* generally appears much like *Vejovis confusus* Stahnke, but differs in the following ways: adult body smaller and less robust (about ⅓ the size of *V. confusus*); base color more whitish-yellow than the more orange-yellow *V. confusus*; faint dusky markings on carapace, dorsum of mesosoma, metasoma V, and telson; obsolete dorsal stripes on mesosoma; ventral side of vesicle smooth, not distinctly granular; palm proportionally more swollen inwardly; and pedipalp chela distinctly less elongate.

Mature males and females about same body size; base color pale to dirty yellow; diffuse dusky pigment on carapace, faint to obsolete; one pair of faint stripes on mesosoma, these obsolete to completely absent; diffuse dusky pigment on telson and metasoma segment V, this faint to absent. Pedipalps with hand only slightly swollen inwardly; with palm keels agranular, much reduced to

obsolete; palm longer than fixed finger but shorter than carapace. Metasoma with inferior lateral keels crenulate to serrate on all segments; inferior median keels present on all segments but reduced in anterior segment, these keels smooth to crenulate anteriorly and approaching serrate condition in fourth segment. Pectinal teeth 16 to 18 in males, 11 to 13 in females.

DESCRIPTION OF HOLOTYPE (male). *Coloration*: Base color of cuticle pale yellow; cuticle almost transparent with heart showing externally; faint dusky pigmentation of carapace, most distinct anteriorly; dark transverse line marks posterior margin of carapace; ocular tubercule black; anterior tergites of mesosoma with faint, submedian, diffuse, dusky pigmentation, forming an obsolete pair of dorsal stripes; faint, diffuse, dusky pigment on metasomal segment V and telson, telson with a pair of ventral, submedian, yellow stripes; pectines slightly whiter in color than sternites; walking legs lighter yellow than dorsum of trunk; pedipalps light yellow except for reddish-amber fingers.

Carapace: Anterior margin straight, with six reddish bristles. Median eyes on raised ocular tubercule; one large, reddish, bristle on ocular tubercule posterior to each eye; diad slightly more than ⅕ carapace width at that point. Carapace surface irregularly covered by abundant large granules; median groove continuous over ocular tubercule, forming deep vertical pit near posterior border of carapace.

Mesosoma: Anterior tergites with large granules, these most abundant postero-laterally; median keels absent on tergite one, indistinct on two, granular on three to six, smooth to granular on seven; tergite seven with two pairs of lateral keels, each set with large dentate to serrate granules; sternites smooth and agranular; with one pair of serrate keels on last sternite.

Metasoma: Lateral keels present and serrate on posterior ¾ of segment I, and posterior ¼ of II and III, absent on IV, present and serrate to crenulate on anterior ½ of V. Inferior lateral keels well developed and serrate on all segments. Inferior median keels distinct on all segments; these keels smooth to crenulate on segments I and II, crenulate on III, crenulate to serrate on IV, serrate on V. Inferior median keels with reddish bristles, three pairs on segments I and II, four pairs on III, five pairs on IV, four pairs on inferior intercarinal space of V.

Telson: Ventral side of vesicle with about 14 long slender reddish hairs, none of these bristle-like; ventral aspect of vesicle agranular, but with uneven surface because of punctate depressions. No distinct subaculear tubercule present.

Pectines: 11 subcircular middle lamellae; 16 teeth per comb. Ventral surface of each fulcrum with three to five reddish bristles; ventral surface of each middle lamella with two to four reddish bristles.

Genital operculum: Completely divided longitudinally; genital papillae visible externally.

Table 1. *Measurements (in millimeters) of* Vejovis gilvus, *new species, holotype and allotype.*

	holotype (male)	*allotype (female)*
Total length	34.4	33.4
Carapace, length	4.2	4.5
width (at median eyes)	3.1	3.2
Mesosoma, length	8.5	10.4
Metasoma, length	16.6	15.0
segment I, (length/width)	2.2/2.5	2.0/2.4
segment II, (length/width)	2.6/2.4	2.3/2.4
segment III, (length/width)	2.7/2.4	2.4/2.3
segment IV, (length/width)	3.6/2.3	3.2/2.2
segment V, (length/width)	5.5/2.2	5.1/2.2
Telson, length	5.1	—
Vesicle, (length/width)	3.9/1.9	3.5/2.2
depth	1.6	1.8
Aculeus, length	1.2	—
Pedipalp		
Humerus, (length/width)	3.1/1.2	3.1/1.1
Brachium, (length/width)	3.4/1.4	3.3/1.5
Chela, (length/width)	5.5/1.8	5.7/1.6
depth	1.8	1.8
movable finger, length	3.1	3.4
fixed finger, length	2.2	2.5
palm, length	3.3	3.2
Pectines, teeth (left/right)	16/16	13/12
middle lamellae	11	9

Chelicerae: Inferior border of movable finger smooth, completely lacking denticles; superior border set with four distinct simple pointed teeth.

Pedipalps: Hand slightly swollen inwardly, keels reduced and agranular. Fixed finger, movable finger and palm each distinctly shorter than carapace; fixed finger distinctly shorter than palm. Pedipalp fingers do not contact along proximal ¾ when fingers closed. Inner margin of fingers only mildly scalloped and with serrate denticles extending almost to proximal inner border.

Standard measurements and photographs: Table 1 and figures 1 and 2.

Description of allotype (female). Approximates holotype in total length, but with relatively longer carapace and mesosoma and shorter metasoma. Base color and color patterns same as holotype with the following exceptions: Diffuse dusky pigmentation reduced on carapace; submedian diffuse pigment of mesosomal tergites slightly more distinct, but dorsal stripes still obsolete; metasomal segment V with diffuse dusky pigment on inferior surface, similar faint dusky pigment subtly underlines inferior median keels of segment IV. Structurally, allotype essentially the same as holotype with the following exceptions: pectines with fewer teeth (13/12 instead of 16/16), middle lamellae reduced in number

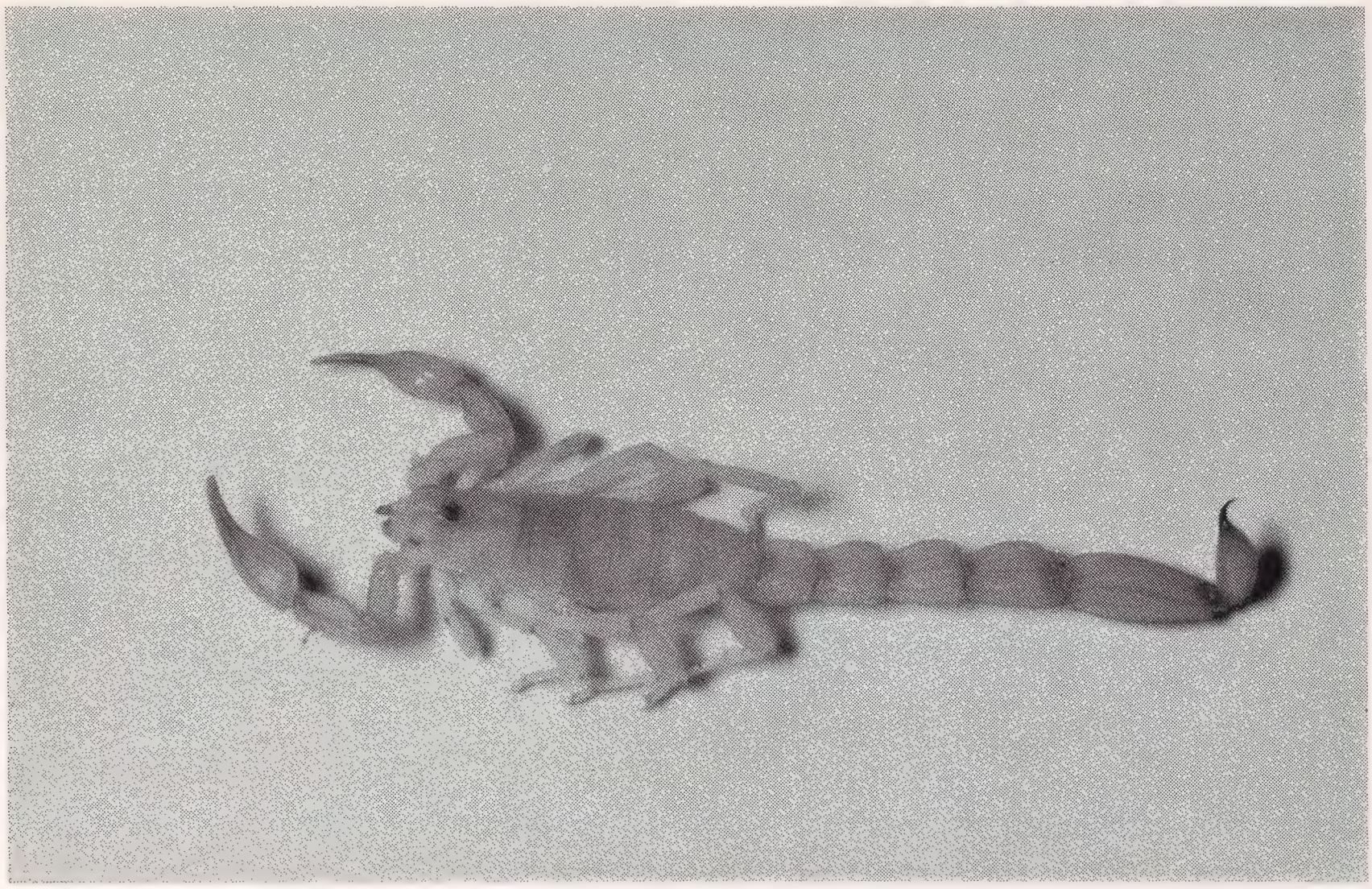

FIGURE 1. *Vejovis gilvus*, new species. Dorsal view of holotype.

(9 instead of 11); no genital papillae, genital operculum not completely divided; carapace and tergites not as heavily granular, even slightly lustrious in places.

Standard measurements: Table 1.

VARIATION WITHIN PARATYPES. Study of seven paratypes (6 males, 1 female) indicated little variation from holotype and allotype. The specimens all appeared mature except that the female was probably subadult. The major differences from the holotype were: diffuse, dusky, pigment of carapace generally reduced to almost absent; dusky, diffuse pigment of tergites reduced or absent; little or no dusky pigment on last metasomal segment of telson; pectinal tooth count varied from 16 to 18 in males, 11 in female; cuticle not as transparent as holotype, appearing more granular on carapace and tergites. Total length varied from 24 to 30.5 millimeters. Mature individuals of both sexes were very similar, main sexual dimorphisms being presence of genital papillae in mature male, slightly longer metasoma in male, and pectine structure.

TYPE DATA AND ETYMOLOGY. The holotype, allotype, and two paratopotypes were collected on white gypsum sand dunes 13 kilometers southwest of Cuatro Cienegas, Coahuila, Mexico, 27 July 1967, by S. C. Williams and W. S. Brown (fig. 3). The holotype and allotype are permanently deposited in the California Academy of Sciences.

This species is named "*gilvus*" because of its light yellowish coloration.

MATERIAL. In addition to the holotype, allotype, and two paratopotypes,

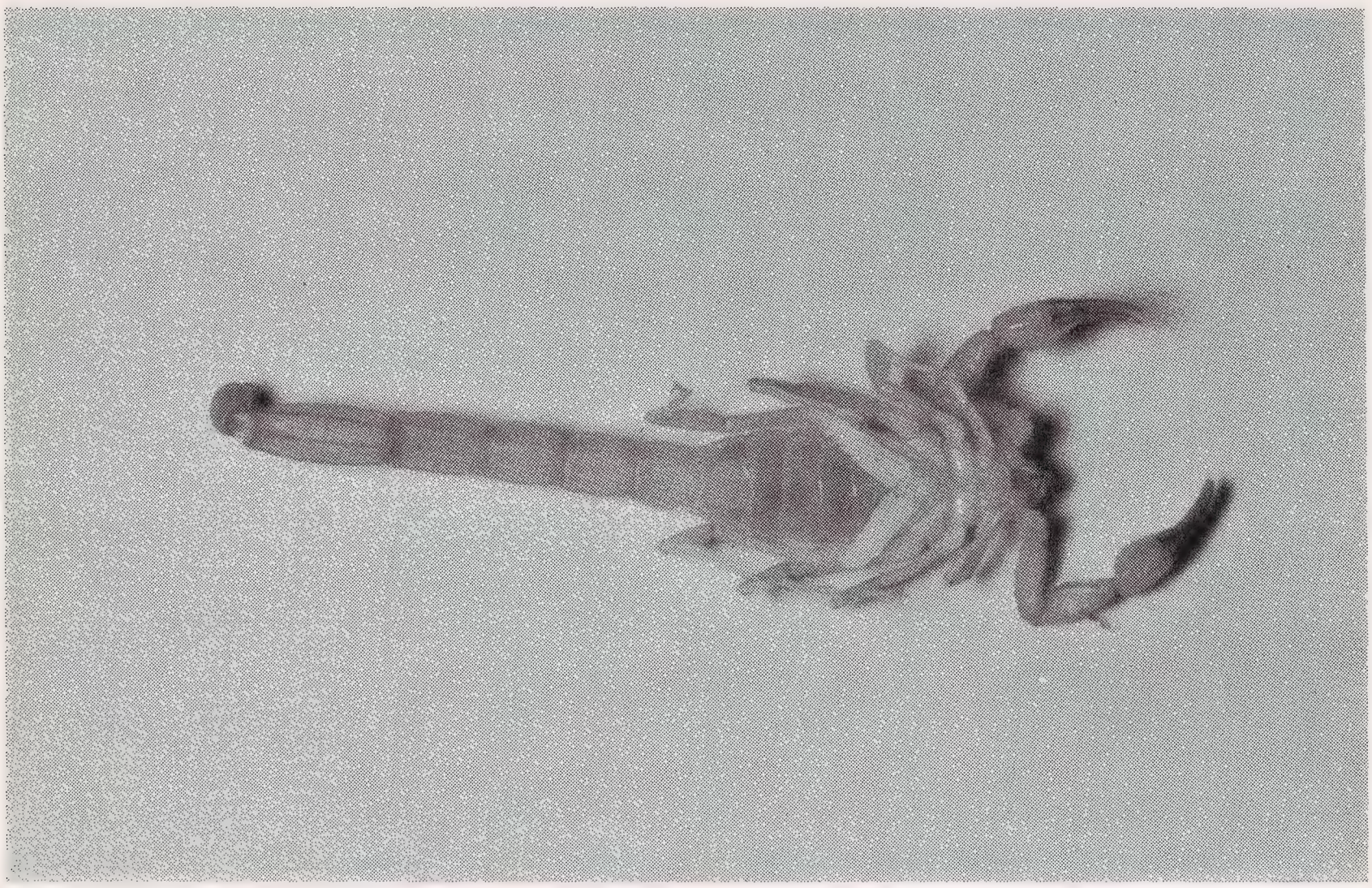

Figure 2. *Vejovis gilvus*, new species. Ventral view of holotype.

six additional paratypes were studied. These were all from the following locations in the Cuatro Cienegas basin of Coahuila, Mexico: Pozos de la Becerra, 14 kilometers southwest of Cuatro Cienegas, 28 July 1967 (S. C. Williams, W. S. Brown), 2 males, 1 female; above Rio Cañon, 4.3 kilometers north northwest of Cuatro Cienegas, 15 August 1967 (W. L. Minckley), 2 males; Travertine Ridge, 13 kilometers southwest of Cuatro Cienegas, 15 August 1967 (W. L. Minckley), 1 male.

Comment. This species is known only from the Cuatro Cienegas basin. Here it was collected in four of the ten localities sampled, but was not abundant in any of these. The specimens collected were predominantly males, and these were mostly adults. All specimens were collected by means of ultraviolet detection.

Vejovis pallidus Williams, new species.
(Figures 4, 5.)

Diagnosis. Large, pale-yellow species of *Vejovis*, completely lacking dark pigmentation except for diffuse, dusky, interocular crescent. Distal tooth on upper margin of movable finger of chelicera reduced in size and far smaller than corresponding tooth of lower margin; denticles present on inferior border of movable cheliceral finger. Pedipalp palms swollen inwardly, and with granular keels. Metasoma long and slender; with all inferior lateral keels distinct, these crenulate to serrate. Pectinal teeth 17 to 20 in female, 25 to 31 in male. Closest

FIGURE 3. White gypsum sand dunes 13 kilometers southwest of Cuatro Cienegas, Coahuila, Mexico. This is the type locality for *Vejovis gilvus*, new species.

relative is probably *Vejovis gracilior* (Hoffmann) based on similar morphology of chelicerae, pedipalp hands, anterior margin of the carapace and general proportions of the metasoma. This species can, however, be distinguished from *V. gracilior* by lack of dark pigmentation on mesosomal dorsum, lack of solid pigment throughout interocular triangle, and structure of inferior metasomal keels. *Vejovis pallidus* should be placed in the subgenus *Paruroctonus* because of the presence of denticles on the inferior border of the movable cheliceral finger.

DESCRIPTION OF HOLOTYPE (male). *Coloration*: Carapace, mesosoma, metasoma and pedipalps uniform pale-yellow; walking legs similar to pedipalps but lighter; pectines almost white. Only contrasting color markings: eyes black, teeth of chelicerae and pedipalps reddish, aculeus dark reddish-brown, tips of pretarsal claws reddish-brown, interocular crescent diffuse and dusky. Cuticle almost transparent, with heart showing dorsally.

Carapace: Anterior margin with median area extending more anterior, no median notch; anterior margin with six reddish bristles; lateral eyes three per group, most anterior eye in each group largest. Median eyes on raised ocular tubercule; one large bristle on ocular tubercule medial to and one posterior to each eye; diad greater than ¼ carapace width at that point. Carapace surface, including ocular tubercule covered with large granules; median groove short, broad, and shallow anterior to ocular tubercule, ends as deep pit near posterior carapace margin.

Mesosoma: All tergites densely covered by large granules; median keels absent on tergites 1 and 2, tergites 3 to 6 with serrate keels on each posterior half, tergite 7 with smooth to serrate keel on middle ⅓ of tergite. Lateral keels only on tergite 7, two pairs present, these dentate medial pair limited to posterior ½ of tergite, lateral pair limited to posterior ⅓ of tergite. Sternites smooth and agranular; one pair of crenulate keels on posterior ⅔ of last sternite.

Metasoma: Lateral keels present and dentate on segment I, represented as four posterior granules on II, represented as three posterior granules on III, absent on IV, crenulate on anterior ⅓ of V. Inferior lateral keels present on all segments: irregularly crenulate on segments I to IV, strongly serrate on V. Inferior median keels on segments I to IV complete and paired, complete and single on V; on segments I to III represented as smooth carinae, on IV smooth to crenulate, on V irregularly serrate. Inferior median keels set with reddish bristles on segments I to IV, 3 pairs on I, 5 pairs on II and III, 7 pairs on IV; ventral surface of segment V with 12 reddish bristles.

Telson: Ventral side with 20 long, reddish hairs, each approximately ⅔ aculeus length, and with more numerous short, whitish hairs. Vesicle basically smooth; with subtle subaculear tubercule.

Pectines: 22 subcircular middle lamellae in linear row; about 5 irregularly placed accessory lamellae between middle row and marginal lamellae; each middle lamella with 3 to 5 reddish bristles; each fulcrum with about 6 to 8 reddish bristles; 29 pectinal teeth. Anterior border of marginal lamellae densely covered by reddish bristles.

Genital operculum: Completely divided longitudinally; large distinct genital papillae visible externally; inferior surface of genital operculum covered with 11 reddish bristles.

Chelicerae: Inferior border of movable finger with three small unpigmented denticles; terminal tooth of superior border of movable finger much shorter than, and not opposing terminal tooth of inferior border.

Pedipalps: Hand swollen inwardly, all keels distinct and covered by large rounded granules; fixed finger distinctly shorter than carapace, movable finger slightly longer than carapace; internal margin of fingers slightly scalloped; teeth extend to proximal end of fingers; no distinct open space between fingers when chela closed.

Standard measurements and photographs: Table 2 and figures 4 and 5.

Description of allotype (female). Essentially the same as holotype in color and morphology with the following exceptions: All metasomal segments slightly reduced in length and width; vesicle of telson longer and wider; pedipalp chela longer but reduced in width and depth; movable and fixed fingers of pedipalp longer, palm longer but not as swollen inwardly; pectines reduced in length and width, with reduced number of teeth (18 instead of 29), with fewer

TABLE 2. *Measurements (in millimeters) of* Vejovis pallidus, *new species, holotype and allotype.*

	holotype (male)	*allotype (female)*
Total length	58.1	56.5
Carapace, length	6.8	7.3
width (at median eyes)	5.6	6.2
Mesosoma, length	14.0	15.3
Metasoma, length	30.3	26.6
segment I, (length/width)	3.8/3.4	3.5/3.2
segment II, (length/width)	4.8/3.2	4.2/2.9
segment III, (length/width)	5.0/3.0	4.6/2.8
segment IV, (length/width)	6.7/2.7	5.7/2.5
segment V, (length/width)	10.0/2.5	8.6/2.6
Telson, length	7.0	7.3
Vesicle, (length/width)	4.2/2.2	4.5/2.6
depth	2.2	2.2
Aculeus, length	2.8	2.8
Pedipalp		
Humerus, (length/width)	5.9/1.8	6.0/2.1
Brachium, (length/width)	5.7/2.4	6.2/2.7
Chela, (length/width)	11.2/3.7	12.3/3.4
depth	4.8	4.6
movable finger, length	6.2	7.1
fixed finger, length	5.2	5.6
palm, length	6.0	6.7
Pectines, teeth (left/right)	29/29	18/18
middle lamellae	22	16

middle lamellae (16 instead of 22); inferior keels of metasoma not as strongly developed, median ones of anterior segments approach obsolescence.

Standard measurements: Table 2.

VARIATION WITHIN PARATYPES. A total of 88 paratopotypes (64 males, 24 females) were studied. The females varied in carapace length from 3.8 to 7.2 millimeters (mode 7.2). The males varied in carapace length from 3.0 to 6.6 millimeters (mode 5.6). Pectinal tooth count varied from 17 to 20 (mode 18 and 19) in females and from 25 to 31 (mode 28) in males. Vesicle of mature females longer and broader than in mature male; pedipalp palm more inwardly swollen on mature male than on mature female; juveniles with less swollen pedipalp hand. Interocular crescent varied from dark and distinct to light and indistinct. The structure, coloration and proportion of paratopotypes were essentially the same as described for holotype and allotype.

TYPE DATA AND ETYMOLOGY. The holotype, allotype, and 88 paratopotypes were collected 0.5 kilometer southwest of Cuatro Cienegas, Coahuila, Mexico, 28 July 1967 by S. C. Williams and W. S. Brown. These specimens were col-

FIGURE 4. *Vejovis pallidus*, new species. Dorsal view of holotype.

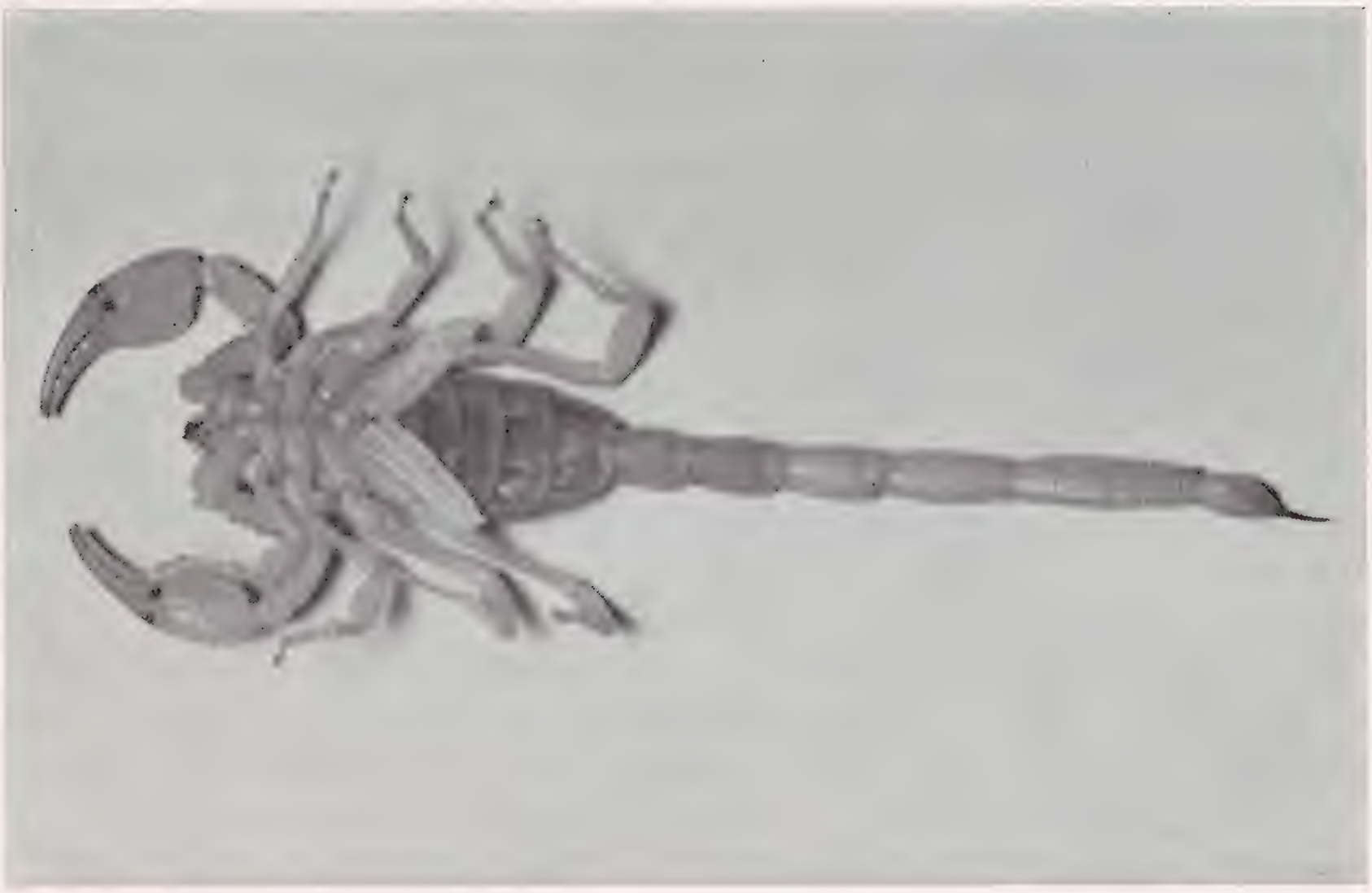

FIGURE 5. *Vejovis pallidus*, new species. Ventral view of holotype.

FIGURE 6. Sandy dune community, 0.5 kilometer southwest of Cuatro Cienegas, Coahuila, Mexico. This is the type locality for the following three new species: *Vejovis pallidus, Vejovis cazieri*, and *Vejovis coahuilae*. Photograph taken by Clarence J. McCoy of the Carnegie Museum.

lected in a sandy, dune community during early evening by means of ultraviolet detection. The holotype and allotype are permanently deposited in the California Academy of Sciences.

This species is named "*pallidus*" because of its pale yellow coloration.

MATERIAL. In addition to the holotype, allotype and 88 paratopotypes, eight paratypes from two other locations within the Cuatro Cienegas basin of Coahuila, Mexico were available for study: 4.3 kilometers north northwest of Cuatro Cienegas, above Rio Cañon, 27 July 1967 (W. L. Minckley), 5 males, 2 females; 4 kilometers east of Cuatro Cienegas, 27 July 1967 (S. C. Williams), 1 female.

COMMENT. This species appears to have preference for sandy habitats, reaching greatest densities in dune communities (fig. 6). This must be almost exclusively a burrowing form as rocks and other surface cover are completely lacking in areas most densely occupied. It was found in three of the 10 habitats sampled within the basin, and was the numerically dominant species in two of these. No distribution record is known outside the Cuatro Cienegas basin. Males significantly outnumbered females by a ratio of more than two to one. Most of the material consisted of adults, but juveniles were also represented in the samples. All specimens were collected by means of ultraviolet detection.

Vejovis cazieri Williams, new species.
(Figures 7, 8.)

Diagnosis. Large species of *Vejovis* with base color of body brownish-yellow; pedipalp fingers contrastingly dark reddish-brown; last metasomal segment and telson contrastingly darker than other caudal segments; one pair of dark dorsal stripes on mesosoma; pedipalp palm swollen inwardly, keels distinct and granular; palm distinctly longer than fixed finger, fixed finger distinctly shorter than carapace; pectines with 16 to 19 teeth in male and 14 to 16 teeth in female. Inferior lateral and median keels of metasoma distinct and granular, not outlined with dark pigment.

Description of holotype (male). *Coloration*: Carapace with general, dark, pigmented markings, posterior margin with dark outline; posterior margin of mesosomal tergites 1 to 6 with dark outline, each tergite with diffuse pigment on each side of midline giving appearance of two dark stripes separated by a pale yellow central stripe; diffuse, dark pigment on most of metasomal segment V and telson; last two pairs of walking legs with portions of femur and patella with faint dusky markings; movable and fixed pedipalp fingers dark reddish-brown; base color of cuticle brownish-yellow, dorsum darker than venter; pectines whitish.

Carapace: Anterior margin with slight median notch and subtle emargination; set with six reddish bristles. Lateral eyes three per group, most anterior eye in each group largest. Median eyes on raised ocular tubercule; one large, erect bristle on ocular tubercule posterior to each eye; diad ⅕ carapace width at that point. Carapace surface with large granules, median groove distinct and lined by large granules over ocular tubercule.

Mesosoma: Dorsal plates densely covered by large granules; median keel absent on segment 1, granular on segments 2 to 7; lateral keels absent on segments 1 and 2, one pair granular on 3 to 6, two serrate pairs on 7. Sternites agranular; one pair of crenulate keels on last sternite.

Metasoma: Lateral keels serrate over most of segment I, present as four posterior granules on II, present as two or three posterior granules on III; absent on IV; crenulate on anterior half of V. Inferior median keels of segments I to IV complete, paired and crenulate; single, serrate to crenulate on segment V. Inferior median keels set with three pairs of large reddish bristles on each of segments I to IV; inferior surface of V set with 10 pairs of reddish bristles. Intercarinal spaces on inferior surfaces of segment V smooth, lacking distinct granules.

Telson: Ventral side with about 20 pairs of long, reddish hairs, many approximating aculeus in length; subtle, subaculear tubercule present; vesicle smooth, lacking granulation.

Pectines: With 14 middle lamellae in a single row; tooth count 18/17; each

TABLE 3. *Measurements (in millimeters) of* Vejovis cazieri, *new species, holotype and allotype.*

	holotype (male)	*allotype (female)*
Total length	45.8	56.1
Carapace, length	5.6	7.4
width (at median eyes)	3.9	5.3
Mesosoma, length	12.8	15.7
Metasoma, length	21.8	25.8
segment I, (length/width)	2.8/2.8	3.4/3.4
segment II, (length/width)	3.4/2.7	4.1/3.3
segment III, (length/width)	3.8/2.6	4.3/3.3
segment IV, (length/width)	4.8/2.4	5.7/3.2
segment V, (length/width)	7.0/2.4	8.3/3.1
Telson, length	5.6	7.2
Vesicle, (length/width)	3.8/2.0	5.0/2.8
depth	1.8	2.2
Aculeus, length	1.8	2.2
Pedipalp		
Humerus, (length/width)	4.4/1.5	5.5/2.0
Brachium, (length/width)	4.8/1.8	5.7/2.4
Chela, (length/width)	8.2/2.9	10.9/3.8
depth	3.0	4.0
movable finger, length	4.3	6.2
fixed finger, length	3.4	5.0
palm, length	4.8	5.9
Pectines, teeth (left/right)	18/17	14/15
middle lamellae	14	11

sclerite of middle lamellae with two or three reddish bristles; each fulcrum with three or four reddish bristles.

Genital operculum: Completely divided longitudinally; large distinct genital papillae visible externally.

Chelicerae: Inferior border of movable finger smooth, completely lacking teeth or denticles.

Pedipalps: Hand swollen inwardly; all keels distinct and covered with large, rounded to smaller granules. Fixed finger distinctly shorter than carapace or palm; internal margin of fingers subtly scalloped, and leave no open space when fingers closed.

Standard measurements and photographs: Table 3 and figures 7 and 8.

DESCRIPTION OF ALLOTYPE (female). Morphologically the same as holotype with the following exceptions: Considerably larger in total length and mesosomal width; other body parts except pectines also proportionally larger; pectines with fewer teeth (14/15 instead of 18/17); middle lamellae reduced in number (11 instead of 14); pectines smaller in total size; no genital papillae; cuticle slightly

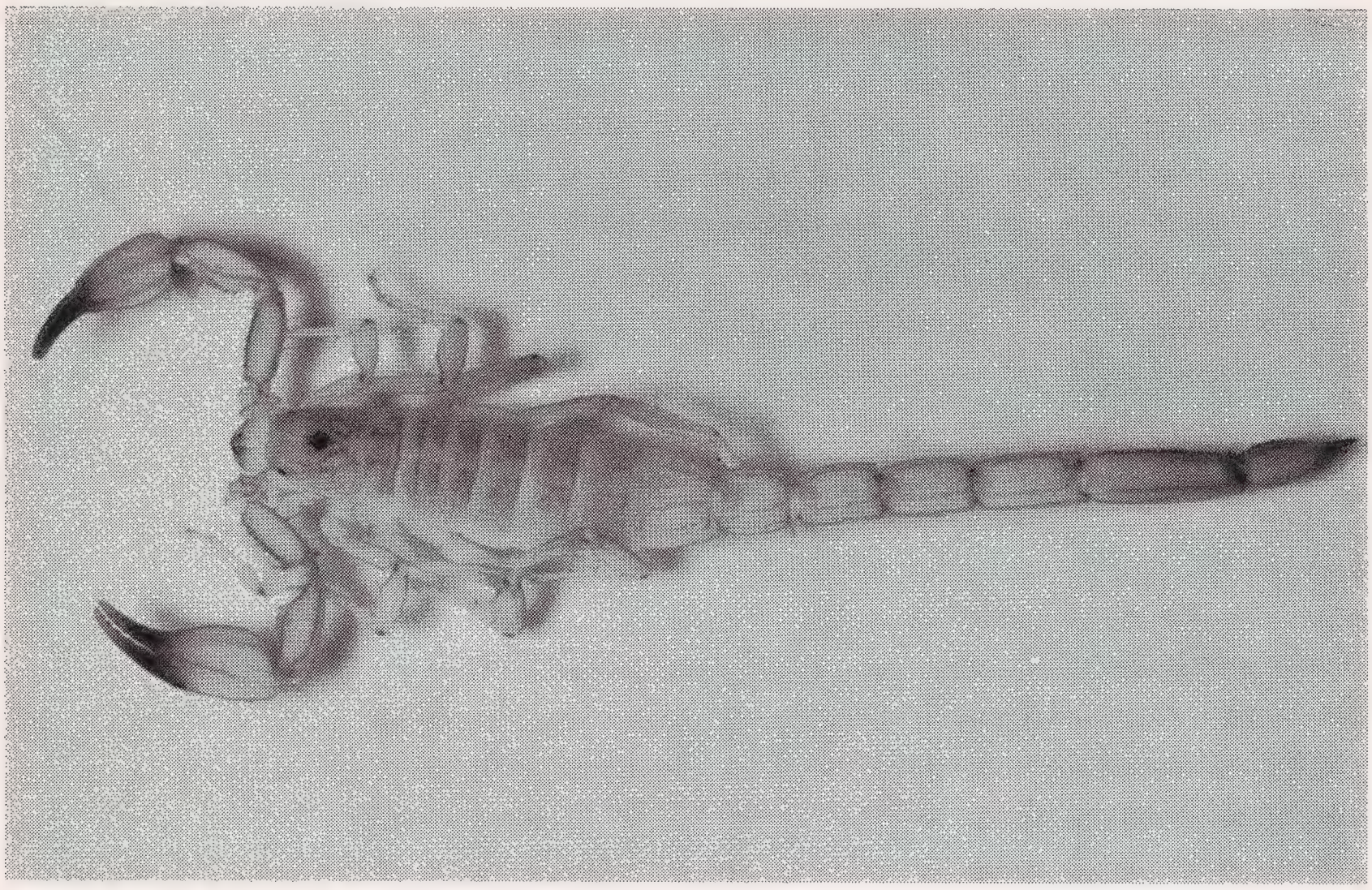

Figure 7. *Vejovis cazieri*, new species. Dorsal view of holotype.

more brownish, appearing somewhat darker; stripes on dorsum of mesosoma not as distinct.

Standard measurements: Table 3.

Variation within paratypes. Study of 21 paratopotypes (19 males, 2 females) indicated little variation from the structure and color of the holotype and allotype. Males varied in carapace length from 2.5 to 6.3 millimeters (mode 5.7), while the two females had carapace lengths of 3.5 and 6.5 millimeters respectively. Pectinal tooth count varied from 16 to 19 (predominantly 17 and 18) in males, and 15 to 16 in females. Almost all specimens with metasomal segment V and vesicle distinctly darker than other caudal segments. All specimens with a pair of dorsal mesosomal stripes, these more diffuse, and less distinct in a few individuals. Carapace markings varied from distinct to obsolete. Juveniles varied from adults in that their pedipalp palms were not as swollen and their dark caudal and pedipalp pigment was more contrasting. Mature females appeared to attain a distinctly larger body size than mature males. Little sexual dimorphism was apparent, sexes best distinguished by pectinal structure and by the presence of genital papillae in the adult male.

Type data and etymology. The holotype, allotype, and 21 paratopotypes were collected 0.5 kilometer southwest of the town of Cuatro Cienegas, Coahuila, Mexico, 28 July 1967, by S. C. Williams and W. S. Brown. The holotype and allotype are permanently deposited in the California Academy of Sciences.

This species is named in honor of Professor Mont A. Cazier, of Arizona State

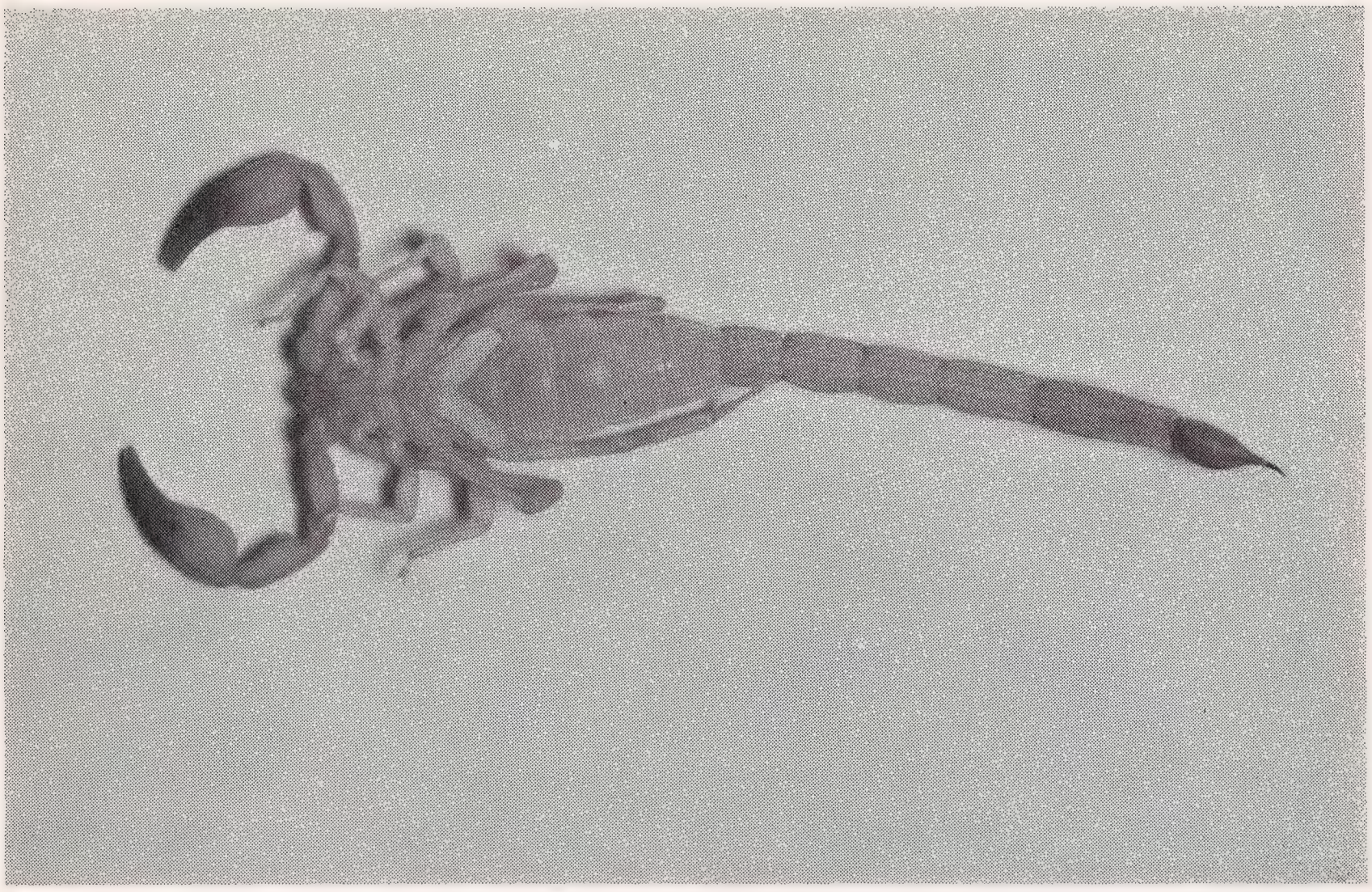

FIGURE 8. *Vejovis cazieri*, new species. Ventral view of holotype.

University, who has significantly contributed to the understanding of the systematics, bionomics, and zoogeography of several insect groups in North America, and who has recently done much to encourage and stimulate students of arachnology.

MATERIAL. In addition to the holotype, allotype and 21 paratopotypes, five other paratypes, all from the Cuatro, Cienegas basin of Coahuila, Mexico, were available for study: Base of San Marcos Mountain, 14 kilometers southwest of Cuatro Cienegas, 28 July 1967 (S. C. Williams), 1 female; 4 kilometers east of Cuatro Cienegas, 27 July 1967 (S. C. Williams and W. S. Brown), 1 male, 1 female; town of Cuatro Cienegas, 5 April 1967 (L. E. Cullum) 1 male; above Rio Cañon, 4.3 kilometers north northwest of Cuatro Cienegas, 15 August 1967 (W. L. Minckley), 1 male.

COMMENT. This species appears to show preference for sandy habitats characterized by fine, silty, sedimentary soils (fig. 6). This must be almost exclusively a burrowing form as rocks and other surface cover are completely lacking in areas most densely occupied. It was found in three of the 10 localities sampled within the basin, and was a numerically subdominant in one of these. No distribution record is known outside the Cuatro Cienegas basin. Males significantly outnumbered females by a ratio of more than four to one (22 males; 4 females). Most of the specimens were mature, but subadults were represented. All specimens were collected by means of ultraviolet detection.

Vejovis coahuilae Williams, new species.

(Figures 9, 10.)

Diagnosis. Medium sized species of *Vejovis* with mature females attaining larger body size than mature males. Body base color dirty yellow; one pair of dark stripes on dorsum of mesosoma; carapace with irregular dusky markings; two pairs of dark stripes underlying inferior keels of metasoma. Pedipalp hands lacking granulation, keels reduced appearing smooth to almost obsolete; inferior keels of metasoma smooth to definitely crenulate; carapace longer than either movable finger, fixed finger or palm of pedipalp; inferior border of movable cheliceral finger completely smooth and lacking denticles; pectinal teeth varying from 13 to 16 in females and 17 to 21 in males.

This species appears related to *Vejovis spinigerus* (Wood) because of similar general coloration, color pattern and general body proportions. It differs from *V. spinigerus* in the following ways: No small, black, submedian tubercules on dorsum of abdomen; metasomal segment IV with dorsal lateral keel ending posteriorly in spine; lateral keels of metasoma not almost obsolete, but well developed and granular on segments I and II; inferior keels of metasoma not all lacking crenulation.

Description of holotype (male). *Coloration*: Base color of body brownish-yellow, this slightly darker on dorsum, pedipalps, and telson; pectines almost white; carapace with areas of distinct dusky pigmentation, this pigment most predominant anteriorly; ocular tubercule almost all black; mesosomal tergites with a pair of amorphous dark blotches separated by an unpigmented area, these forming a pair of dark dorsal stripes; dorsum of metasomal segments I, II, and V with faint diffuse dark pigmentation; all inferior median and inferior lateral keels of metasoma with underlying diffuse dark pigment, this pigment extending into the intercarinal spaces of segments IV and V; vesicle venter with diffuse dark pigment except for a pair of longitudinal yellow stripes; pedipalp with fingers reddish-amber and faint, diffuse, dusky pigment on palm underlying positions of keels; faint dusky pigmentation on humerus and brachium; walking legs with faint dusky pigment on femur and patella.

Carapace: Anterior margin with subtle median emargination, and set with eight reddish bristles. Lateral eyes three per group, anterior two about equal in size, posterior eye definitely smallest of three. Median eyes on raised ocular tubercule, one pair of reddish bristles on ocular tubercule anterior to eyes and a similar pair posterior to eyes; diad slightly more than ⅕ but less than ¼ the carapace width at that point. Carapace surface irregular and densely covered with large granules.

Mesosoma: Posterior lateral region of tergites 1 to 6 densely covered with large rounded granules; medium keels present and granular on tergites 2 to 7; tergite 7 with two pairs of lateral keels on posterior ⅔; these serrate to dentate.

TABLE 4. *Measurements (in millimeters) of* Vejovis coahuilae, *new species, holotype and allotype.*

	holotype (male)	*allotype (female)*
Total length	38.6	47.9
Carapace, length	4.9	6.2
width (at median eyes)	3.7	4.8
Mesosoma, length	9.8	13.0
Metasoma, length	18.5	21.8
segment I, (length/width)	2.5/3.0	3.0/3.7
segment II, (length/width)	2.8/3.0	3.4/3.5
segment III, (length/width)	3.0/2.9	3.6/3.5
segment IV, (length/width)	4.0/2.9	4.7/3.5
segment V, (length/width)	6.2/2.8	7.1/3.4
Telson, length	5.4	6.9
Vesicle, (length/width)	3.8/2.0	4.9/2.8
depth	1.7	2.3
Aculeus, length	1.6	2.0
Pedipalp		
Humerus, (length/width)	3.8/1.4	4.3/1.7
Brachium, (length/width)	4.1/1.7	5.1/2.2
Chela, (length/width)	6.7/2.4	8.4/2.7
depth	2.6	2.8
movable finger, length	3.6	4.4
fixed finger, length	2.6	3.6
palm, length	4.1	4.8
Pectines, teeth (left/right)	20/21	14/16
middle lamellae	14	11

Sternites agranular, with many reddish bristles; one pair of keels on last sternite, this smooth to crenulate.

Metasoma: All dorsal and dorsolateral keels serrate to dentate except that dorsal keels of segment V absent, these keels on segments I to IV terminate posteriorly as an enlarged spine; lateral keels complete and serrate on segment I, crenulate on posterior ½ of II, present as about four irregular dentate to crenulate granules on posterior ¼ of III, absent on IV, irregularly serrate to crenulate on anterior ½ of V; inferior lateral keels present on all segments, these smooth to crenulate on I and II, serrate on III to V; inferior median keels absent on segment I, smooth to crenulate on II and III, crenulate to serrate on IV, single and serrate on V. Inferior median keels set with reddish bristles, 3, 4, 5, 5 pairs on segments I to IV respectively, inferior intercarinal space of segment V with 12 pairs of large reddish bristles; inferior intercarinal space of segment V mostly smooth, but with several small groups of granules.

Telson: Ventral aspect of vesicle smooth and lustrous, lacking granulation,

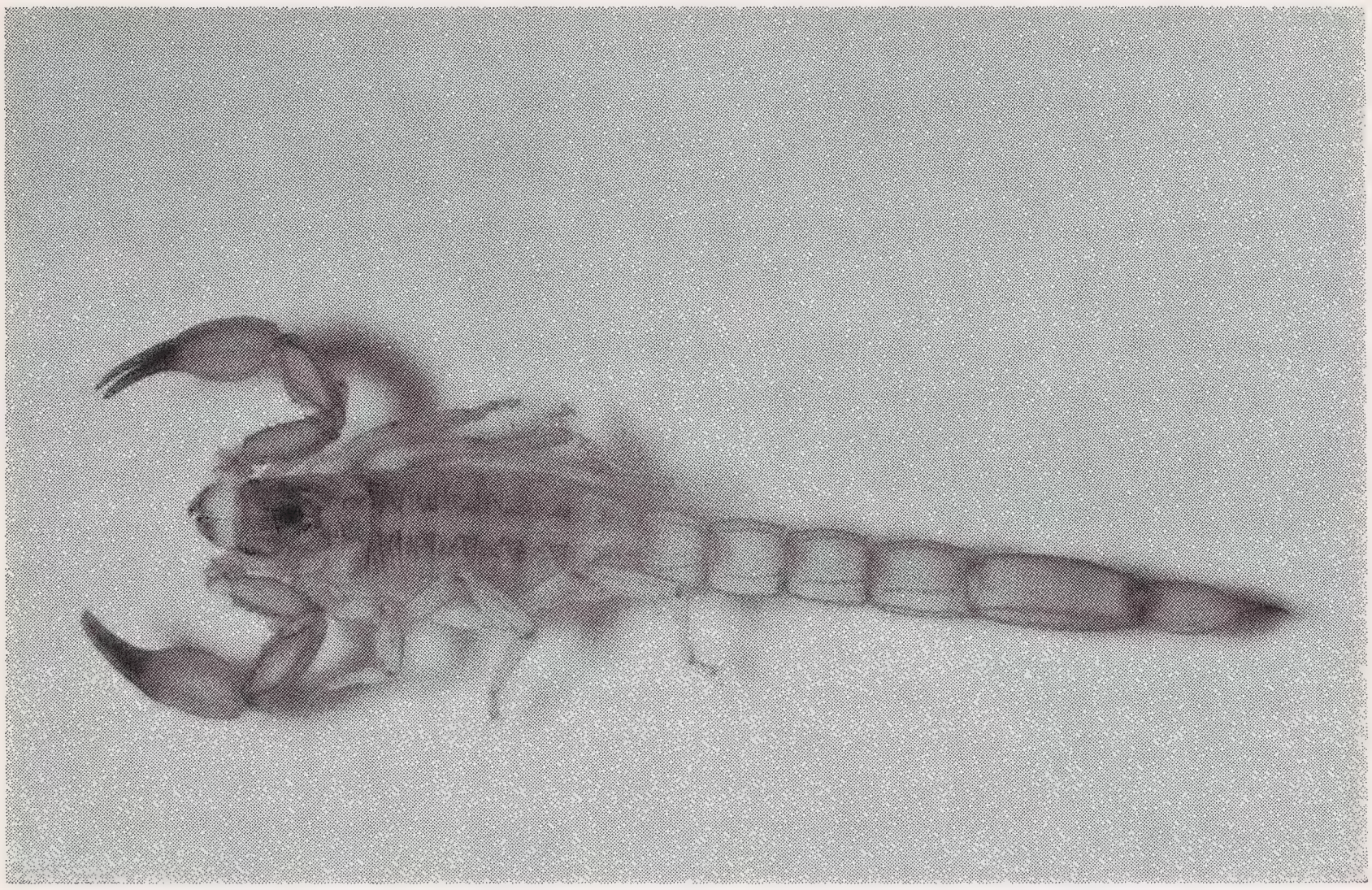

Figure 9. *Vejovis coahuilae*, new species. Dorsal view of holotype.

with 30 to 35 long reddish bristles approximating aculeus in length; broad subaculear tubercule.

Pectines: 14 subcircular middle lamellae; 20/21 pectinal teeth. Each middle lamella with 2 to 4 reddish hairs, each fulcrum with 3 to 6 reddish hairs.

Genital operculum: Completely divided longitudinally; distinct genital papillae visible externally; 6 large reddish bristles on surface.

Chelicerae: Inferior border of movable finger completely lacking denticles; superior border with large basal tooth, two small equal sized middle teeth, and one large terminal tooth. Median and median inferior aspects of fixed finger base densely hirsute.

Pedipalps: Palms moderately swollen inwardly; keels present as reduced, agranular carinae; surface of hand smooth and lustrous. Palm, fixed finger and movable finger each shorter than carapace length. Grasping edge of fingers not deeply scalloped; teeth of proximal ⅓ of fingers do not contact when fingers closed, but leave distinct open space between fingers.

Standard measurements and figures: Table 4 and figures 9 and 10.

Description of allotype (female). Coloration and patterns essentially the same as holotype except that allotype has faintly darker base color and less distinct dark markings. Structure is essentially the same as holotype except: Body size larger; keels on palm less distinct to obsolete; pectines with fewer middle lamellae (11 instead of 14), fewer teeth (14/16 instead of 20/21); with-

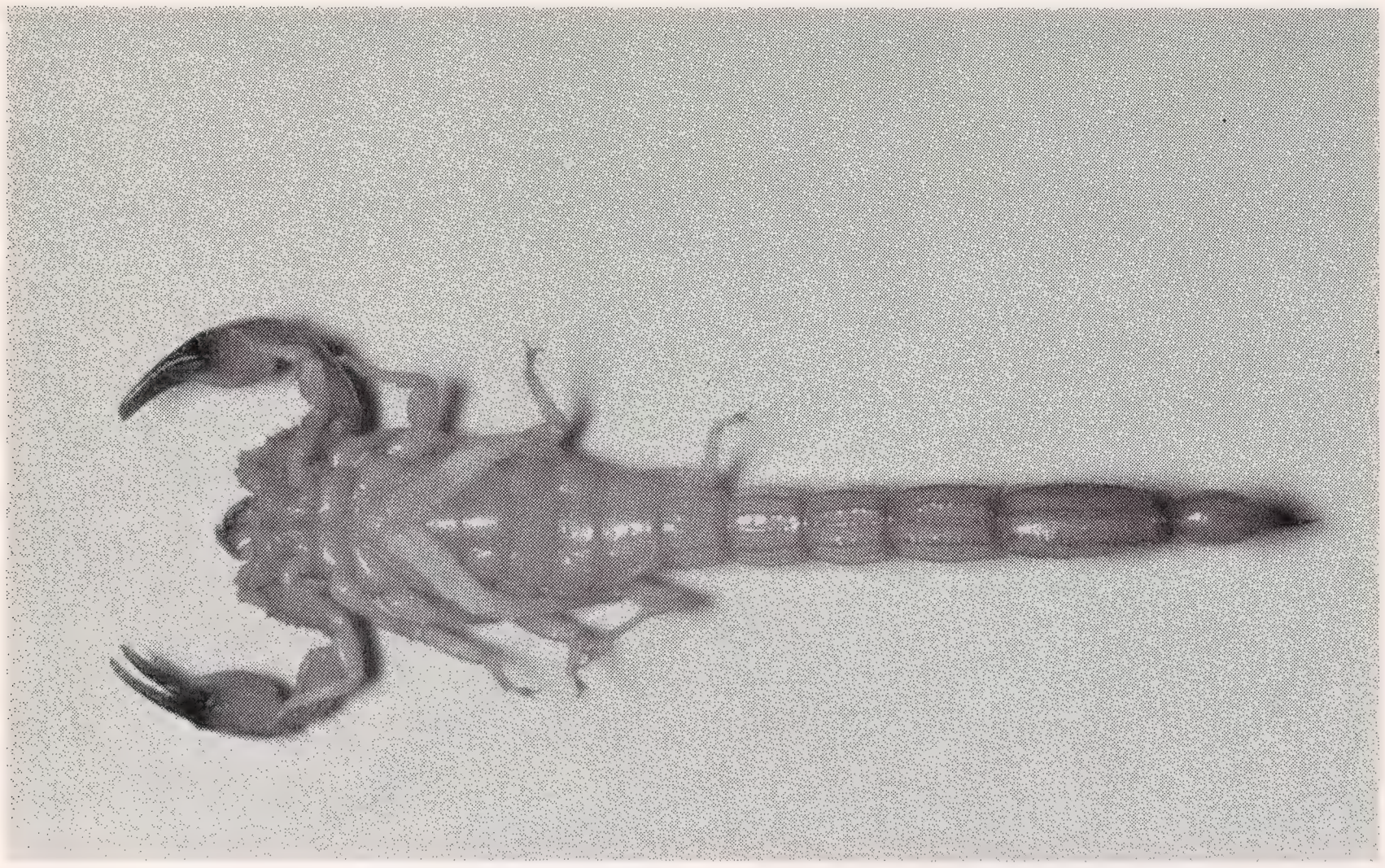

FIGURE 10. *Vejovis coahuilae*, new species. Ventral view of holotype.

out genital papillae; palm less swollen inwardly, no proximal open space when pedipalp fingers closed.

Standard measurements: Table 4.

VARIATION WITHIN PARATYPES. Study of 43 paratopotypes (19 males, 24 females) indicated little variation from the description of holotype and allotype. Males varied in carapace length from 1.5 to 5.3 millimeters (predominantly 5.0), while females varied from 1.5 to 6.3 millimeters (predominantly 5.4). Most specimens of both sexes appeared to be mature. Mature females appeared to be somewhat larger in most body proportions than were mature males. A definite tendency toward the obsolescence of both the keels and pigment on inferior surface of metasoma I was apparent. Little sexual dimorphism occurred except for, body size, structure of the pectines and presence of genital papillae. Both sexes were similar in coloration and other body proportions. Young instars were similar to adults except that: Pedipalps more heavily pigmented on all segments; metasomal segment V more heavily pigmented and much more contrasting; pedipalp hands more elongate, without inwardly swollen palm and with movable finger longer than palm. Pectine teeth 13 to 16 (predominantly 14 and 15) in females, and 17 to 21 (predominantly 19) in males.

TYPE DATA AND ETYMOLOGY. The holotype, allotype, and 43 paratopotypes were collected 0.5 kilometer southwest of Cuatro Cienegas, Coahuila, Mexico, 28 July 1967 by S. C. Williams and W. S. Brown (fig. 6). The holotype and allotype are permanently deposited in the California Academy of Sciences.

TABLE 5. *Measurements (in millimeters) of* Vejovis minckleyi, *new species, holotype and paratype.*

	holotype (male)	*paratype (male)*
Total length	62.5	56.6
Carapace, length	7.4	6.6
width (at median eyes)	5.6	4.9
Mesosoma, length	15.8	15.3
Metasoma, length	31.9	27.9
segment I, (length/width)	4.4/3.5	3.8/3.3
segment II, (length/width)	5.0/3.6	4.5/3.1
segment III, (length/width)	5.6/3.5	4.8/3.0
segment IV, (length/width)	7.3/3.2	6.3/2.8
segment V, (length/width)	9.6/3.1	8.5/2.8
Telson, length	7.4	6.8
Vesicle, (length/width)	4.8/2.8	4.3/2.2
depth	2.4	1.9
Aculeus, length	2.6	2.5
Pedipalp		
Humerus, (length/width)	8.3/1.9	7.4/1.4
Brachium, (length/width)	8.3/2.2	7.4/1.8
Chela, (length/width)	13.0/2.8	11.7/2.5
depth	3.6	3.1
movable finger, length	9.8	7.8
fixed finger, length	8.2	7.2
palm, length	5.6	5.0
Pectines, teeth (left/right)	32/32	32/31
middle lamellae	—	23

This species is named *coahuilae* after the Mexican state, Coahuila, in which it was first collected.

MATERIAL. In addition to the holotype, allotype, and 43 paratopotypes, 48 additional paratypes were observed from nine other localities in Coahuila and Texas. These records are as follows: Mexico, Coahuila: Laguna Tio Candido, 14 kilometers south of Cuatro Cienegas, 15 April 1965 (W. L. Minckley), 2 females; Laguna Churince, 16 kilometers south of Cuatro Cienegas, 24 December 1965 (W. L. Minckley, C. O. Minckley) 3 females; town of Cuatro Cienegas, 5 April 1967 (L. E. Cullum), 3 females; 4 kilometers east of Cuatro Cienegas, 27 July 1967 (S. C. Williams, W. S. Brown), 10 males, 17 females; Pozos de la Becerra, 14 kilometers southwest of Cuatro Cienegas, 28 July 1967 (S. C. Williams, W. S. Brown), 2 males, 1 female; gypsum sand dunes, 13 kilometers southwest of Cuatro Cienegas, 27 July 1967 (S. C. Williams, W. S. Brown), 2 males, 2 females; Travertine Ridge, 12 kilometers southwest of Cuatro Cienegas, 15 August 1967 (W. L. Minckley), 1 female; above Rio Cañon, 4.3 kilometers north northwest of Cuatro Cienegas, 15 August 1967 (W. L. Minckley), 1 male,

2 females. Texas (U. S. A.), Pecos County: Wil Banks Ranch, 16 kilometers north of Fort Stockton, 27 December 1966 (R. Winokur), 1 male, 1 female.

COMMENT. This species showed the widest distribution of any scorpion in the Cuatro Cienegas basin, and was found in 9 of the 10 localities sampled. It occurred in sandy as well as rocky habitats, and was found on the gypsum dunes. Some preference was shown for sandy habitats as this species reached its greatest density in sandy, dune-type habitats where it was numerically subdominant. The specimens collected on the white gypsum dunes were distinctly lighter in base color, and had dark markings reduced as compared to specimens taken in other habitats. One distribution record is known from outside the Cuatro Cienegas basin, Pecos County, Texas. The Texas specimens studied did not differ significantly from those collected in the Cuatro Cienegas basin. Females were encountered in the samples significantly more frequently than were males (35 males to 54 females), and juveniles were not common among the samples. Most specimens were collected by means of ultraviolet detection, but a number were also by rock-rolling.

Vejovis minckleyi Williams, new species.
(Figures 11, 12.)

FIGURE 11. *Vejovis minckleyi*, new species. Dorsal view of holotype.

DIAGNOSIS. Extremely large species, ranking among the largest species of *Vejovis* described. General body color uniform light yellow; pedipalp fingers contrastingly marked with reddish-brown. Carapace, mesosoma, and metasoma

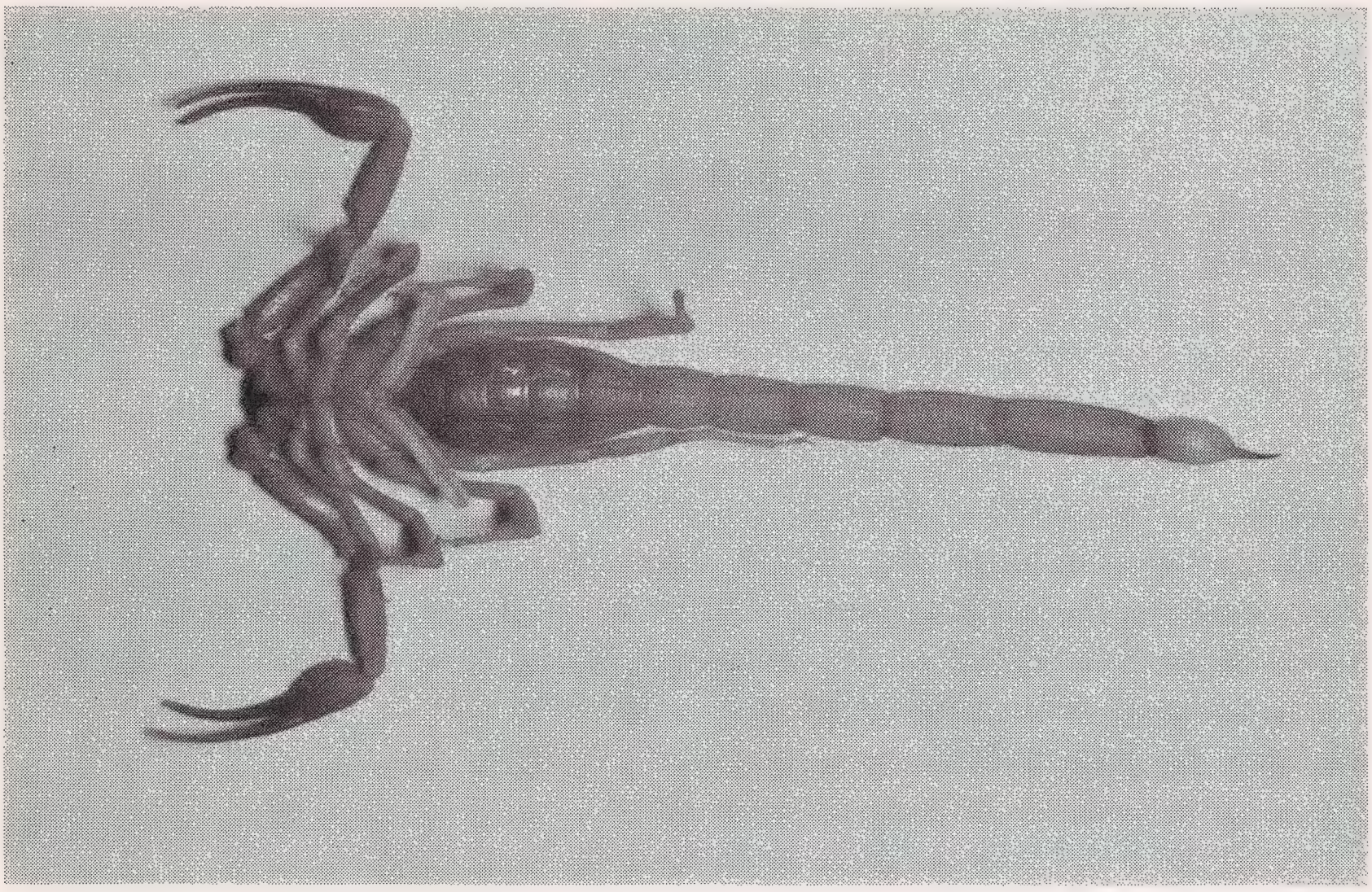

Figure 12. *Vejovis minckleyi*, new species. Ventral view of holotype.

without contrasting color markings. Inferior median keels of metasoma reduced and smooth except that on segment IV they are more prominent and crenulate; inferior lateral keels of segments I to IV crenulate. Movable finger of pedipalp distinctly longer than carapace or palm and approximates metasoma V in length. Male with large pectine containing 32 teeth. Movable finger of chelicera with inferior border lacking denticles.

Description of holotype (male). *Coloration*: Base color of body light yellow; walking legs slightly lighter than body; pectines white; median and lateral eyes black; fingers of pedipalps contrastingly reddish-brown, hand orange, aculeus reddish-brown. The entire body uniform in color, lacking other markings.

Carapace: Distinct notch in midanterior border; median groove running length of carapace, but with distinctly deeper pit in posterior region; three lateral eyes on each anterolateral corner, anterior two being similar size and larger than the third; two median eyes on raised tubercule located ⅖ of carapace length from anterior border; each median eye with one, short, stout bristle posteriorly on ocular tubercule; width of ocular diad slightly over ⅙ of carapace width at that point; entire carapace surface densely covered by granules. Median groove lined on posterior aspect of ocular tubercule by a row of large granules.

Mesosoma: Each tergite densely covered with granules; median keel on segments 3 to 7 present and granular; one pair of lateral keels on segments 3 to 6 faint and irregularly granular; two pair of distinct dentate lateral keels on

FIGURE 13. Eastern tip of San Marcos Mountain, 12 kilometers southwest of Cuatro Cienegas, Coahuila, Mexico. This is the habitat of the paratype specimen of *Vejovis minckleyi,* new species.

tergite of segment 7. Sterna agranular; sternite of segment 7 with two pairs of keels, median pair smooth, lateral pair well developed and crenulate.

Metasoma: Inferior median keels obsolete to faint on segments I to II, faint and crenate on III, crenate on IV, single and serrate on V. Inferior lateral keels distinct and serrate on all segments. Superior keels distinct and serrate on segments I to IV, absent on V. Superior lateral keels distinct and serrate on first four segments, but irregularly granular on V. Median lateral keels almost complete and finely crenulate on segment I; serrate but present only on posterior ⅕ of II; composed of four small posterior serrations on III; absent on IV; present and crenulate on anterior ¾ of V.

Telson: Basically smooth, but with irregular surface depressions; vesicle covered inferiorly by approximately 20 to 25 long reddish hairs, these hairs approximately ½ length of aculeus.

Pedipalps: Chela distinctly elongate; palms moderately swollen inwardly; keels on hand well developed and covered with sharp serrate or large rounded granules; carapace distinctly shorter than either movable or fixed finger, but longer than palm; fixed finger longer than palm; internal border of fingers subtly scalloped but with one pronounced proximal scallop; each finger ends distally in a large overhanging, terminal tooth.

Chelicerae: Inferior border of movable finger smooth to crenate.

Pectines: With genital papillae protruding externally from genital operculum; genital operculum completely divided longitudinally.

Standard measurements and photographs: Table 5 and figures 11 and 12.

Paratype variation. The paratype, also a mature male, did not differ significantly from the structure and coloration of the holotype other than being slightly smaller in size.

Type data and etymology. The holotype was collected 5.3 kilometers northwest of Cuatro Cienegas, Coahuila, Mexico, 3 January 1965, by W. S. Parker. The paratype was collected in the second canyon from the eastern tip of San Marcos Mountain, 12 kilometers southwest of Cuatro Cienegas, 3 January 1965, by W. L. Minckley, W. S. Parker, and W. K. Taylor (fig. 13). The holotype is permanently deposited in the California Academy of Sciences.

This species is named "*minckleyi*" in honor of Professor W. L. Minckley, Arizona State University, who has enthusiastically studied the unique biology of the Cuatro Cienegas basin over the last several years, and who collected many of the first scorpion specimens known from this area.

Comment. The holotype was collected inside a cave, 20 meters from the entrance, on an exposed wall. The paratype was collected under a rock on powdery soil not associated with a cave. This species is known only from these two specimens.

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No. 69, 11 pages, 12 figures. September 25, 1968

Balanus hopkinsi, New Species, and *B. balanus* (Linnaeus, 1758) (Cirripedia, Thoracica) from Plio-Pleistocene Sediments on Tjörnes, Northern Iceland

By

Victor A. Zullo

California Academy of Sciences

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ABSTRACT: *Balanus* (*Balanus*) *hopkinsi*, a new species bearing close resemblance to *B. eburneus* Gould, 1841, occurs in the Tjörnes sediments of late Pliocene or earliest Pleistocene age on Tjörnes, northern Iceland, where it is associated with a temperate Atlantic molluscan fauna. The overlying early Pleistocene Breidavík sediments contain the boreo-arctic barnacle *B.* (*B.*) *balanus* (Linnaeus, 1758) in association with extant molluscs of a colder water aspect.

INTRODUCTION

A collection of barnacles made in the course of a re-study of the Pliocene and Pleistocene sediments of Tjörnes in northern Iceland (fig. 1) by Thorleifur Einarsson, Icelandic University Research Institute and David M. Hopkins, United States Geological Survey, Menlo Park, California, includes a new species of *Balanus* (*Balanus*) and *B. balanus* (Linnaeus, 1758). The species are mutually exclusive in their stratigraphic distribution throughout the sequence (fig. 2). *Balanus balanus*, an extant boreo-arctic barnacle, occurs in the Breidavík sediments of early Pleistocene age together with a molluscan fauna characterized by species of Pacific ancestry and cold water aspect. The new species occurs in the stratigraphically lower Tjörnes sediments of late Pliocene or earliest Pleistocene age. These deposits are below the earliest indication of glaciation in the sequence (2.4–3.0 million years ago) and contain a number of

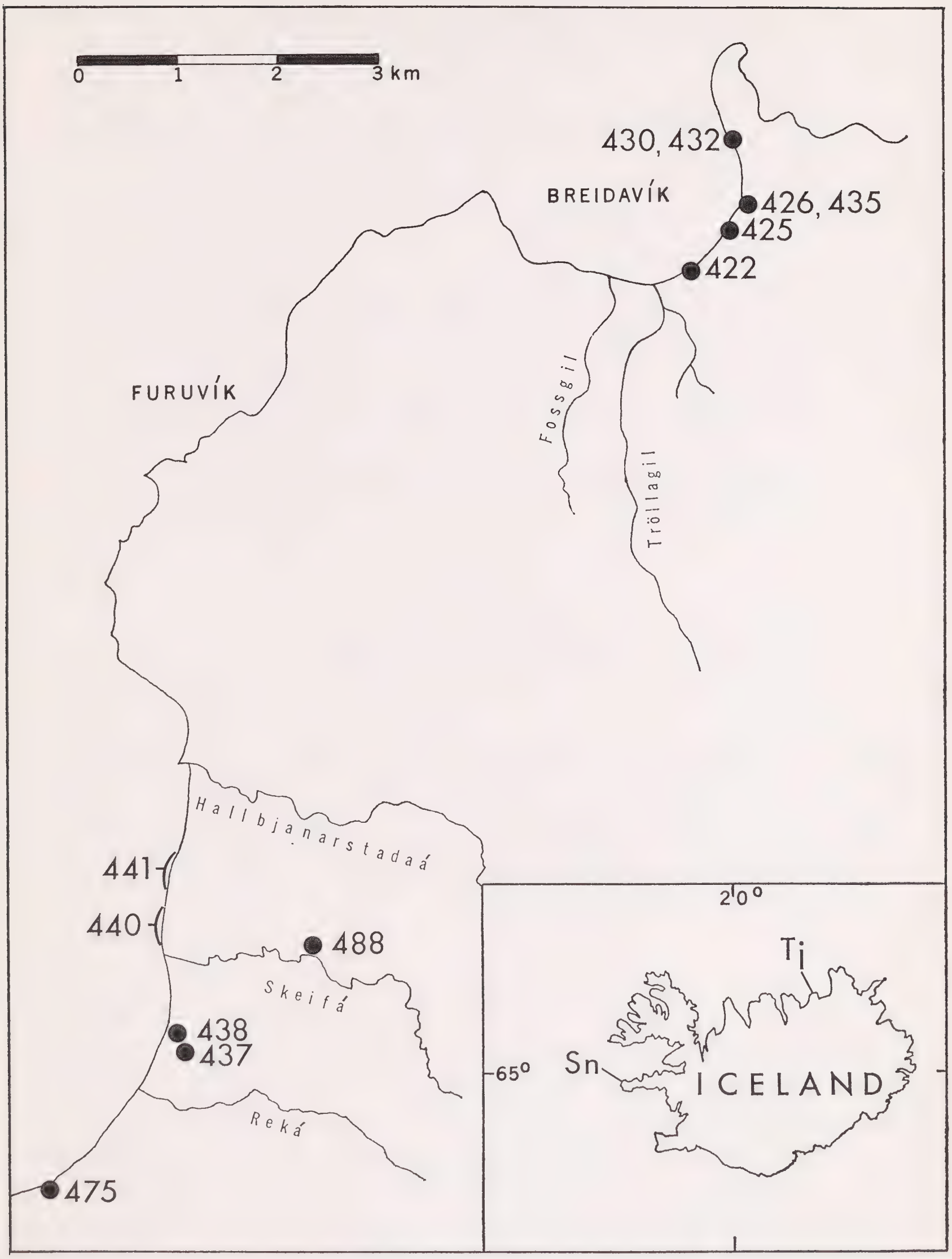

Figure 1. Map of barnacle localities on Tjörnes peninsula, northern Iceland. Inset indicates location of Tjörnes (Tj) and Snaefellsnes (Sn) in Iceland.

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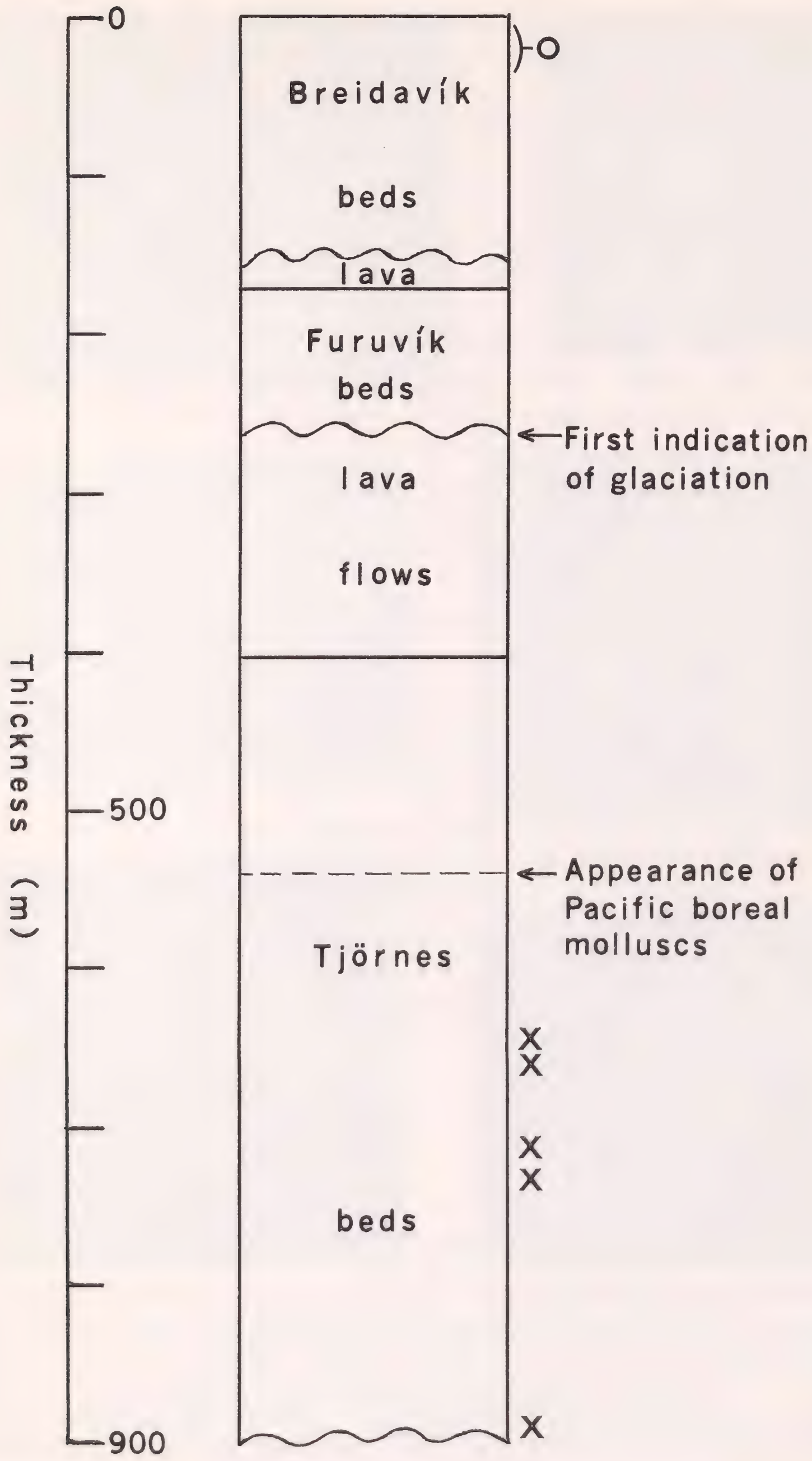
Figure 2. Part of Tjörnes sequence illustrating stratigraphic distribution of *Balanus balanus* (◯) and *B. hopkinsi* (×) (modified after Einarsson *et al.*, 1967).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Appearance of
Pacific boreal
molluscs
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molluscs whose northern limits are now to the south (Hopkins *et al.*, 1965; Einarsson *et al.*, 1967). This new species is described as follows:

Balanus (Balanus) hopkinsi Zullo, new species.

(Figures 3–10.)

Diagnosis. Smooth walled, conic *Balanus* strict sense, with broad radii, transversely septate parietal and basal tubes, strongly arched scutum with external longitudinal striae, and trident shaped tergum with long, narrow, pointed spur.

Description. Shell (figs. 9–10) high conic to tulipiform, strongly bent towards short, acutely concave carina; orifice diamond shaped, toothed, as broad or broader than base; parietes smooth, with numerous ovate longitudinal tubes crossed throughout by closely spaced transverse septa; radii broad with denticulate sutural edges and oblique summits that make about a 45° angle with direction of growth; alae broad with less oblique summits; interior sharply ribbed below sheath; basis calcareous, with transversely septate tubes.

Scutum (figs. 5, 7, 8) strongly warped between base and apex; exterior with conspicuous growth ridges crossed by fine, but obvious longitudinal striae; striae best developed over narrow, pigmented longitudinal bands sometimes present on lower two-thirds of scuta (fig. 8); adductor ridge short, straight, erect, placed about midway between articular ridge and occludent margin; upper end of adductor ridge higher than and not confluent with or approaching articular ridge; articular ridge broad, one-half to two-thirds length of tergal margin, reflexed; no depressor muscle pit observed.

Tergum (figs. 3, 4, 6) trident shaped, flat; carinal side of basal margin with deep, V-shaped notch; scutal side similarly, but less deeply notched; tergal spur long, narrow, about one-fifth width of basal margin, and terminating in acute point on scutal side; depressor muscle crests well developed on carinal lobe.

Measurements	lateral diameter	carinorostral diameter	rostral height
Paratype USNM 161401	17 mm.	19.4 mm.	18.7 mm.
Paratype USNM 161403 (conic)	14 mm.	15 mm.	21.1 mm.
Paratype USNM 161402 (tulipiform) about	10 mm.	13 mm.	31 mm.

Occurrence. Specimens of *B. hopkinsi* were collected at the following six localities in the Tjörnes sediments (after Hopkins, personal communication, 1964):

475B (Type Locality)	Bed A of Bárdarson (1925). Landslide block on south bank of the mouth of Kaldakvisl, representing the lowest bed in

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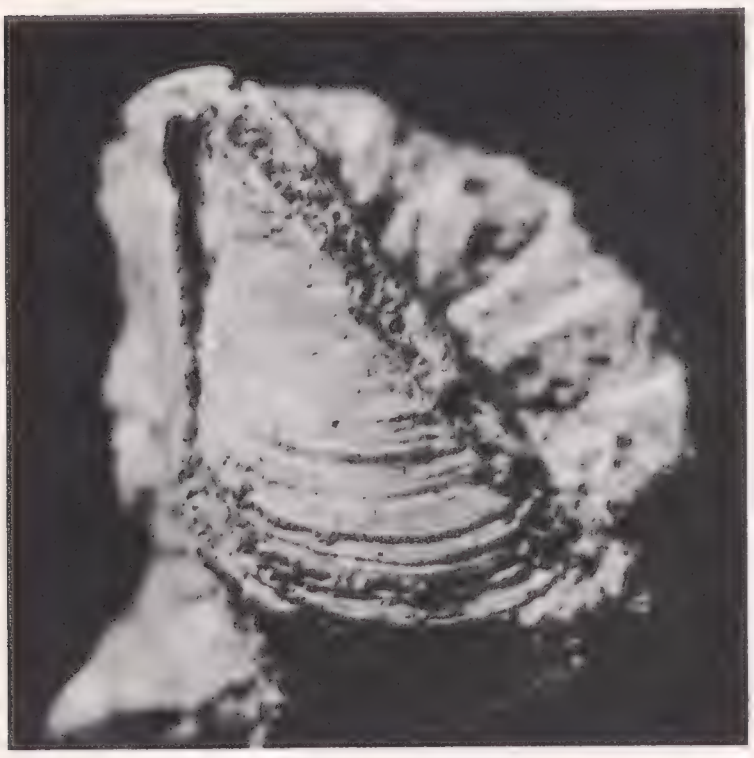

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FIGURES 3–8. *Balanus (Balanus) hopkinsi* Zullo, new species. (3) Tergal interior, (4) tergal exterior, (5) scutal interior, Holotype (USNM cat. no. 161398; loc. 475B), height of tergum 8.5 mm; (6) tergal exterior, (8) scutal exterior, Paratype (USNM cat. no. 161399; loc. 475B), height of tergum 8.2 mm; (7) scutal exterior, Paratype (USNM cat. no. 161400; loc. 488B), height of scutum 9.5 mm.

	the Tjörnes sediments, resting unconformably on Tertiary basalts, 66° 86.3′ N, 17° 17.5′ W.
438E	*Balanus horizon* supposedly at top of Bed 7, but because of landsliding possibly part of Bed 8, Lindarlaekjarfoss, 66° 07.1′ N, 17° 15.9′ W.
437	Base of Bed 8, just above coal bed D, swale halfway between Lindarlaekur and mouth of Reká.
488B	Bed 9, west end of cutbank on north side of Skeifá, just upstream from road, 66° 07.7′ N, 17° 14.0′ W.
440B	Bed 9, between Skeifarfoss and Brunngil, 66° 07.5′ N, 17° 16.0′ W.
441B	Middle and upper part of Bed 10, Stollen, 66° 07.9′ N, 17° 15.9′ W to 66° 08.25′ N, 17° 15.8′ W.

Disposition of type material. Holotype and paratypes deposited in the U. S. National Museum, Washington, D. C. Holotype USNM cat. no. 161398 and paratypes USNM cat. nos. 161399, 161402, 161403 from locality 475B. Paratype USNM cat. no. 161401 from locality 440 B. Paratype USNM cat. no. 161400 from locality 488B.

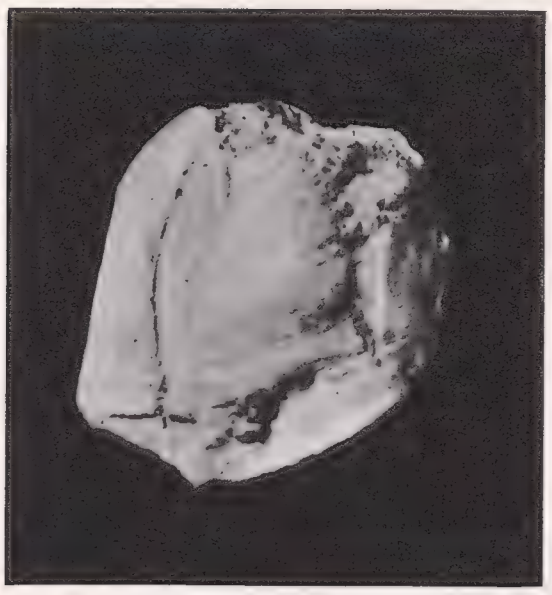
Remarks: *Balanus hopkinsi* is similar and no doubt closely related to the extant western North Atlantic species *B. eburneus* Gould, 1841 that ranges from Rio de Janeiro north into Massachusetts. The new species can, however, be readily distinguished through comparison of the opercular valves. The scutum of *B. eburneus* is nearly flat and strongly striate longitudinally, whereas that of *B. hopkinsi* is markedly arched and the striae, although distinct, are less deeply incised in all specimens examined. The adductor ridge of the scutum is also differently placed in the two species. In *B. eburneus* the apical end nears or is confluent with the basal end of the articular ridge, but in *B. hopkinsi* the adductor ridge is removed from the articular ridge and apically terminates higher on the scutum. The tergal spurs are quite different. That of *B. eburneus* is relatively short, broad, and is basally truncate, whereas the new species has a longer, narrower spur that is pointed basally.

The shell and terga of the West African species *B. pallidus* Darwin, 1854 (including *B. pallidus stutsburi* Darwin, 1854) are somewhat similar to those of *B. hopkinsi,* but the scuta of the former lack longitudinal striae.

Balanus (Balanus) balanus (Linnaeus).

(Figures 11, 12.)

Balanus balanus occurs in glacial deposits of the upper part of the Breidavík sediment sequence on Tjörnes and the lower part of the Búlandshöfdi sediment sequence of Snaefellsnes, western Iceland (fig. 1). These deposits are stratigraphically higher than the rocks containing *B. hopkinsi* and succeed an



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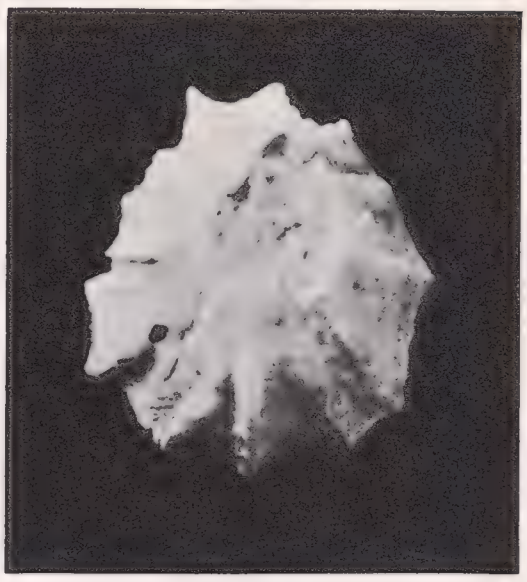

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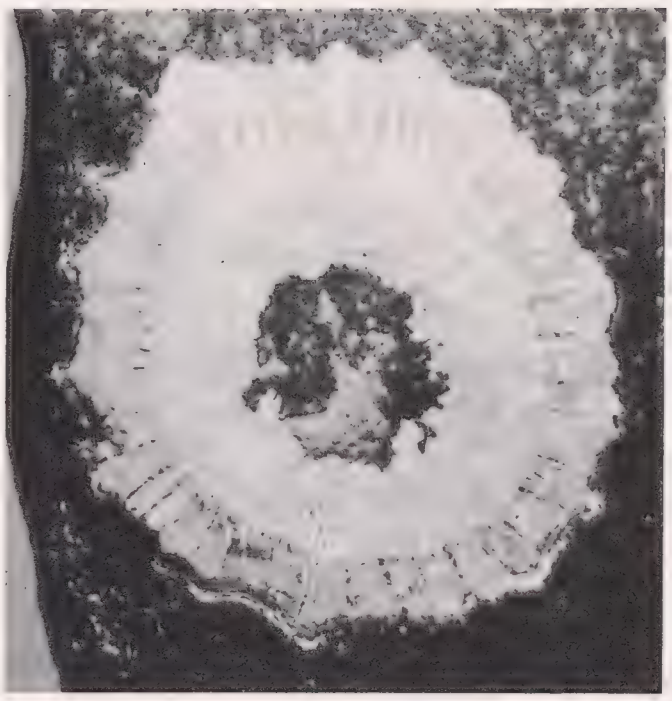

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FIGURES 9–10. *Balanus (Balanus) hopkinsi* Zullo, new species. (9) High conic shell, Paratype (USNM cat. no. 161401; loc. 440B), height 17.5 mm; (10) tulipiform shell, Paratype (USNM cat. no. 161402; loc. 475B), height 31.4 mm.

FIGURES 11–12. *Balanus (Balanus) balanus* (Linnaeus). (11) Shell, Hypotype (USNM cat. no. 161405; loc. 426B), carinorostral diameter 15.2 mm; (12) basis on rock, Hypotype (USNM cat. no. 161404; loc. 435B), greatest diameter 29.3 mm.

influx of boreal molluscs of Pacific origin. Remains of this barnacle were obtained from the following eight localities in Iceland:

Breidavík sediments, Tjörnes

432B	From scree blocks on beach derived from Beds 12 and 14 near Torfhóll, 66° 12.0′ N, 17° 09.0′ W.
430B	Scree block probably derived from base of Bed 14, but possibly from Bed 12. On beach at Torfhóll, 66° 12.0′ N, 17° 09.0′ W.

432F	From 1 m of Bed 14, Torfhóll, 66° 12.0′ N, 17° 09.0′ W.
426B	Conglomerate bed at base of Bed 12 just north of Svarthamar, 66° 11.7′ N, 17° 08.7′ W.
435B	Same locality as 426 B.
422C	Bed 9 in shore cliffs between Tröllagil and Svarthamar, 66° 11.3′ N, 17° 09.5′ W.
425B	Bed 8b at Svarthamar, 66° 11.5′ N, 17° 09.0′ W.

Bulandshöfdi sediments, Snaefellsnes

536B	Búlandsgil sediments exposed in dry waterfall back of small electric power plant at Ólafsvík. Specimens are from upper and lower claystone, in iceberg sediment formed near icefront, 64° 53.3′ N, 23° 42.0′ W.

Extant *B. balanus* is a boreo-arctic species ranging from 80° North latitude to Long Island Sound and the English Channel in the Atlantic, and Puget Sound and the Kurile Islands in the Pacific, from the lower intertidal (in northern waters) to about 300 m depth (Broch, 1924; Pilsbry, 1916). This species (= *B. porcatus* of authors) has been reported from several Pleistocene localities in northern Europe and North America, including the Red and Mammaliferous Crags of England, the glacial deposits of Udevalla, Sweden, Skien, Norway, Island of Bute, Scotland, and eastern Canada (Darwin, 1854), Spitzbergen and Greenland (vide Feyling-Hanssen, 1953), and late Pleistocene terrace deposits in Oregon and glacio-marine sediments in southeastern Alaska (Zullo, 1966). *Balanus balanus* was previously reported from the Pleistocene of western Iceland by Bárdarson (1921) together with *B. crenatus* Bruguière, 1789 and *Balanus* species.

The numerous Tertiary reports of *B. balanus* from Europe are open to question. Kolosváry (1955, p. 184) listed it from the Miocene of Italy, England, France, Germany, the USSR, Belgium, and Sweden, and Davadie (1963, p. 69), in repeating these localities, stated that this species is common in the Pliocene of Italy and Sicily and abundant in the lower Helvetian of France. Kolosváry's list of Miocene localities must in part be a typographical error, for there are no known marine deposits of definite Miocene age in England. This record, together with that from Sweden, probably was meant to refer to Darwin's (1854) Pleistocene localities. Few of the Tertiary specimens referred to *B. balanus* have been illustrated, and the only ones to come to my attention (those of Alessandri, 1906, pl. 17, figs. 16–17, and Menesini, 1966, pl. 26, figs. 3–7) from the Miocene and Pliocene of Italy are definitely not of that species.

It is quite possible that most, if not all of the Tertiary identifications of *B. balanus* are incorrect. Certainly Miocene hydroclimates of Europe were quite warmer than the boreo-arctic waters to which extant *B. balanus* is restricted. Hence, if the Miocene records were assumed to be correct, it would

force the conclusion that this species had lived first under one, then another set of climatic conditions, had markedly altered its physiological tolerances to meet these climatic changes, but had maintained its morphological identity. In view of this seemingly untenable set of circumstances, it is suggested that a more critical examination be made of the Tertiary barnacles assigned to *B. balanus*.

Zoogeographic Implications

The distribution of barnacles in the sequence on Tjörnes follows the paleoclimatic and zoogeographic conclusions presented by Einarsson *et al.* (1967). *Balanus hopkinsi* occurs exclusively in the lowest "Tapes" zone and the middle "Mactra" zone which are typified by shallow water and littoral sediments intercalated with thin lignite seams and lacustrine beds. The molluscs of these zones are primarily Atlantic in character, but include a few warm water species of Pacific origin that are postulated to have taken advantage of a Miocene opening of the Bering land bridge to migrate via the northern Arctic route. This molluscan fauna and the pollen flora of the lignites suggest a milder temperate climate than is present in Iceland today.

The upper "Cardium" zone of the Tjörnes sediments is characterized by an influx of boreal molluscs of Pacific origin and a corresponding elimination of the species typical of the lower zones. The first indications of glaciation in the Tjörnes sequence (2.4–3.0 million years ago) are found in the Furuvík beds which consist of a sequence of marine and glacio-marine sediments interbedded in the lavas separating the Tjörnes and Breidavík sediments. No barnacles were collected either from the "Cardium" zone or the Furuvík beds, but the modern boreo-arctic species *B. balanus* was obtained from the stratigraphically higher Breidavík sediments. These sediments are composed of interbedded lavas and glacial deposits that contain a modern boreo-arctic molluscan fauna.

It is impossible at present to determine whether *B. hopkinsi* is part of the ancestral stock group of extent *B. eburneus* or a diversification from *B. eburneus* itself. Fossils ascribed to *B. eburneus* are few (*e.g.*, Pilsbry, 1918, 1924) and being based on shells alone, are not conclusive. It is possible to hypothesize that *B. hopkinsi* was of Atlantic origin and was eliminated from northern Iceland by the cooling of marine hydroclimates preceding glaciation.

If the Tertiary European records of *B. balanus* can be ignored, it is tempting to suggest that this species was part of the major invasion of Pacific marine invertebrates into the boreal Atlantic during the periodic Pleistocene inundations of Bering land bridge. However, the Pacific fossil record of *B. balanus* is scanty and undiagnostic, and although it has a potential ancestor in the Pacific *B. rostratus* Hoek, 1883 stock, much more information is needed before any conclusion can be made concerning the origin of *B. balanus*.

Acknowledgments

I wish to thank Drs. David M. Hopkins and Thorleifur Einarsson for providing the specimens used in this study, and for their advice during the preparation of the manuscript.

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No. 70, 3 pages, 2 figures, 1 table. September 25, 1968

Extension of Range for *Balanus tintinnabulum californicus* Pilsbry, 1916 (Cirripedia, Thoracica)

By

Victor A. Zullo

California Academy of Sciences

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ABSTRACT: The northern limit of *Balanus tintinnabulum californicus* Pilsbry, 1916, previously recognized as San Francisco, California, is extended northward about 429 kilometers to Humboldt Bay, California.

Balanus tintinnabulum californicus Pilsbry, 1916, previously known to range from the Gulf of California north to San Francisco, California (Henry, 1960), is represented in the collection of the California Academy of Sciences (CAS) by specimens from four localities between San Francisco and Eureka, California (table 1; figs. 1, 2). The specimens from Mendocino and Humboldt counties were taken from navigational buoys serviced by the USS *Lupine* in 1939, and were presented to the late Frank L. Rogers for identification. Additional material was collected both by F. L. Rogers and me from shore localities along the Marin and Sonoma County coasts. These new records extend the range of this subspecies about 429 kilometers to the north.

Balanus nubilus Darwin, 1854 was the most abundant barnacle on the buoys, except in Humboldt Bay (CAS loc. 29692) where *B. crenatus* Bruguière, 1789 was also found in large numbers. The few individuals of *B. tintinnabulum californicus* obtained might indicate that their presence was fortuitous, and related to abnormal, short-term conditions that allowed settlement and growth during the 1939 season. However, two lines of evidence suggest that the northern California coast is part of the established range of this subspecies.

Haderlie (1968, pp. 335, 337; table 3) in a study of settlement and growth of fouling organisms on test panels in Monterey Harbor, found that *B.*

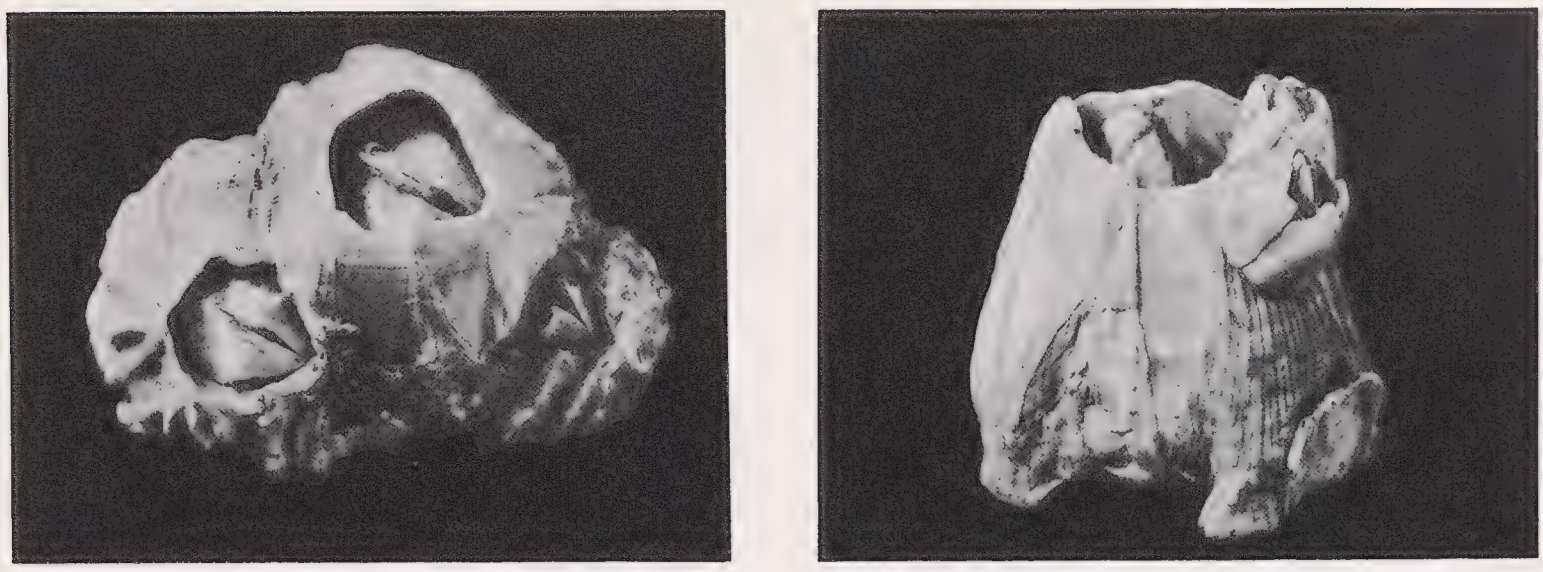

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FIGURE 1. *Balanus tintinnabulum californicus* Pilsbry (center) with *B. nubilus* Darwin. Rodgers Break buoy, Humboldt County (CAS loc. 33294), carinorostral diameter of orifice 13.5 mm.

FIGURE 2. *Balanus tintinnabulum californicus* Pilsbry with *B. crenatus* attached. Humboldt Bay buoy, Humboldt County (CAS loc. 29692), carinorostral diameter of orifice 16.4 mm.

tintinnabulum californicus did not settle on panels exposed for three months or less, but was present on panels exposed between six and twelve months. He concluded that this barnacle might require the presence of an established biota before settlement could take place. According to F. L. Rogers' notes, the buoys tended by the USS *Lupine* were hauled and cleaned about four times a year. Extrapolation of the settling data from Monterey Harbor could thus explain the low frequency of *B. tintinnabulum californicus* on these buoys.

A single specimen of *B. tintinnabulum californicus* has also been found in

TABLE 1. *Northern California localities of* Balanus tintinnabulum californicus *Pilsbry.*

CAS locality no.	Locality	Collector	Specimens
40767	Bolinas, Marin County	F. L. Rogers	1, beachworn
40766	Carmet Beach, Sonoma County	V. Zullo, Feb. 3, 1962	1, low intertidal
29689	Albion whistle buoy, off entrance to Albion River, Mendocino County	D. H. Heagerty, USS *Lupine*, 1939	(see note below)
33294	Buoy off Rodgers Break, near Punta Gorda, Humboldt County	D. H. Heagerty, USS *Lupine*, 1939	1
29692	Buoys in Humboldt Bay, Humboldt County	D. H. Heagerty, USS *Lupine*, 1939	2 (1 dead)

NOTE: The specimens recorded by F. L. Rogers from this locality could not be found.

a late Pliocene deposit at Moonstone Beach in the Eureka area (University of California Museum of Paleontology, Berkeley, loc. B-7346). The large and diverse invertebrate fauna of this locality is composed predominantly of extant species that indicate hydroclimatic conditions not unlike those presently found off the coast at Eureka. Initially, this fossil occurrence in association with a cool temperate fauna so far to the north of the presumed northern limits of the subspecies was difficult to interpret. However, the Recent records now available serve to resolve this problem, and, conversely, the late Pliocene record suggests that the northern range of *B. tintinnabulum californicus* has long been established.

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The Use of Copper Sulfate as a Medicament for Aquarium Fishes and as an Algaecide in Marine Mammal Water Systems

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Aquarists for years have known that although copper can be lethal, small amounts have a beneficial effect on certain fishes. The use of a penny in a small aquarium tank or a bit of copper screen had long been a practice of some early hobbyists. The utilization of copper in large tanks by professional aquarists did not come about until some 22 years ago when Marineland of Florida became plagued by many fish ectoparasites, as well as considerable amounts of algae. There was a need for some means of combating parasites and algae. As a result of this need, Max Gelfand (1946) started his investigations of the use of copper in water systems. He tested various copper-complexing agents in order to discover a means of preventing copper precipitation in alkaline water. By adding appropriately selected chemical compounds (sequestering agents) to alkaline water, he found that the copper ions were maintained in solution. At pH values as high as 10.5, copper ions remained in solution and proved to be effective in removing algae and certain parasites from the water.[1]

Independently, research at the Steinhart Aquarium (Dempster, 1955) led

[1] Gelfand's discovery was patented by the Department of Commerce, U. S. Patent Office (no. 2,400,863, May 21, 1946). On 1 April 1949 he assigned the entire right, title, and interest in his invention and patent to Black Laboratories, Inc., Gainesville, Florida, which on the same date assigned the entire right, title, and interest to Marine Studios, Inc., Marineland, Florida. The method for the use of copper compounds sequestered with aliphatic hydroxy acids in water treatment was kept highly secret for many years; consequently this method of algae and disease control in alkaline water was not available to aquariums other than Marineland.

to the development of a copper–citric acid solution that is stable in sea water. The ratio of 3 parts of copper sulfate pentahydrate to 2 parts of citric acid monohydrate by weight has proved satisfactory. This copper–citric acid solution is used in the treatment of diseased fish.

The success of this therapy suggested the use of sequestered copper as a means of controlling algae in marine mammal tanks, and parasites in fish tanks.

Copper compounds must be utilized with considerable caution since they are toxic not only to animal parasites and algae but also, in varying degrees, to all forms of life. Therefore, when copper is added to water circulating through fish tanks or to water circulating through marine mammal tanks, its toxic effect on the animals must be seriously considered.

There is wide variation among the animals and plants in their tolerance to copper. Most forms of algae and diatoms have a greater degree of tolerance to it than do the vast majority of fishes; consequently, a lethal copper concentration for these phytoplanktonic organisms will most likely be lethal to fish. Thus it is impractical and could be disastrous to use copper as an algaecide in fish tanks. Because of the high sensitivity of sea anemones, starfish, nudibranchs, and other invertebrates to copper, its use is precluded in aquarium tanks containing these forms. Marine mammals appear to tolerate copper concentrations up to 1 ppm. Most forms of algae succumb at a concentration of this level; therefore, copper compounds may be used successfully as an algaecide in water systems housing marine mammals if the copper is sequestered.

Fishes vary considerably in their ability to tolerate copper. The squirrel-, goat-, turkey-, and some of the butterfly-fishes are the first of the marine forms to show signs of distress when the copper concentration exceeds 0.2 ppm. It has been the experience at the Steinhart Aquarium that most marine fishes will tolerate a concentration of 0.15 $\pm$ 0.05 ppm. for a 10-day treatment period. However, 0.2 ppm. should be considered the upper limit, and the concentration should not fall below 0.1 ppm. or the effectiveness of the treatment will be diminished. Even though some fishes may not exhibit signs of distress when the copper concentration exceeds 0.2 ppm. it is neither advisable nor necessary to subject them to higher concentrations, as pathogenic flagellates and ciliates will succumb to the lower concentrations when treatment is extended over the ten-day period.

Although the copper treatment is primarily used as a cure for gill diseases caused by dinoflagellates of the genus *Oodinium*, the Steinhart experience has been that many other fish diseases caused by protozoan organisms respond to this therapy. It may also be used successfully as a prophylactic measure to counteract diseases introduced by newly arrived wild fishes. Treatment with this chemical for one week will free the fish of many of their external protozoan parasites.

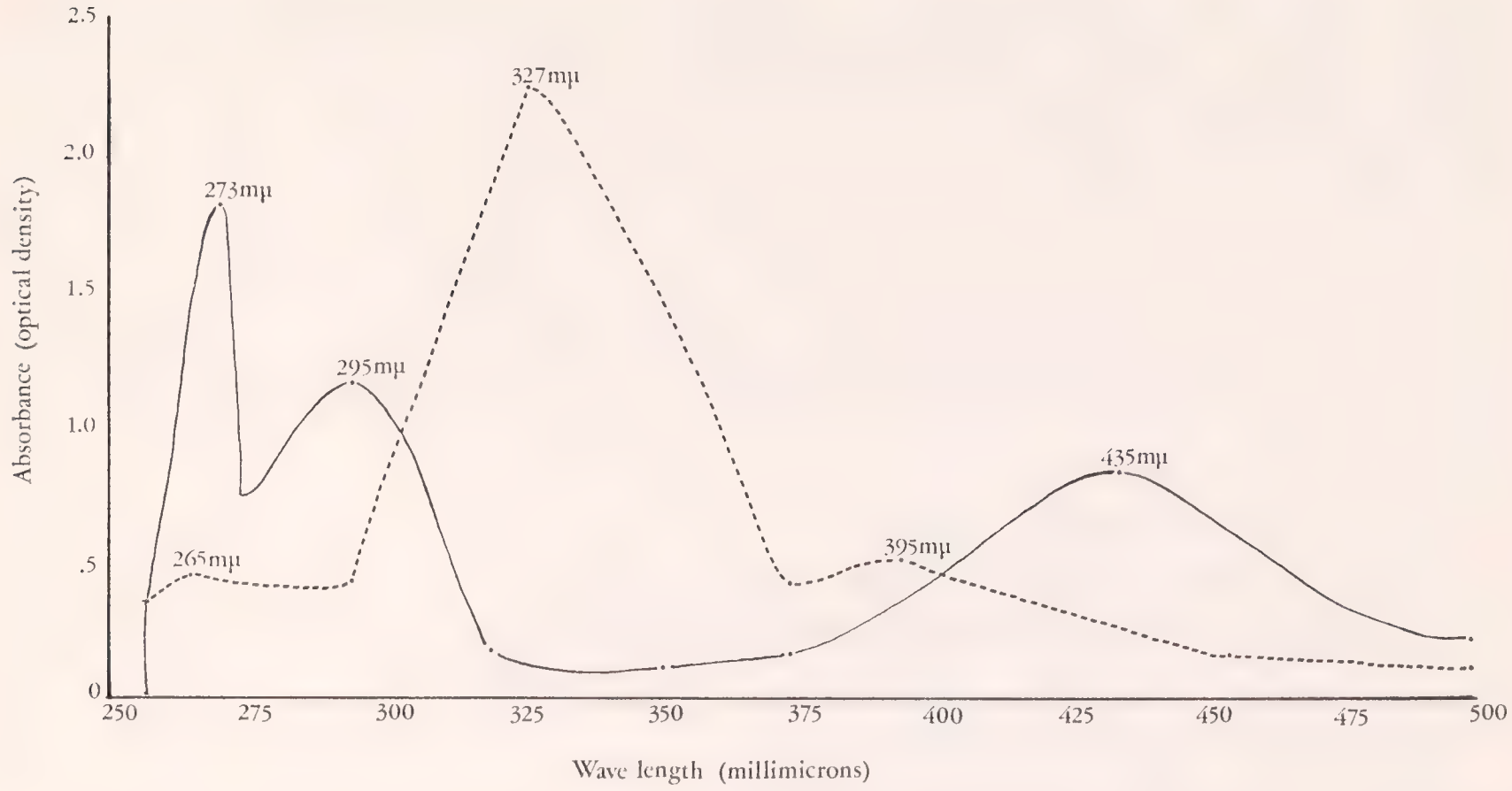

FIGURE 1. Absorption spectra of copper diethyldithiocarbamate (solid line) and nickel diethyldithiocarbamate (broken line) in carbon tetrachloride at concentrations of 1.4 and 1.3 ppm. respectively.

In aquarium water systems where newly collected tropical marine fishes are regularly introduced, it is advisable to treat the water routinely with copper once a month. This will substantially reduce the incidence of disease in aquarium tanks. After each copper treatment, water from the aquarium system should be gradually renewed with fresh sea water and the filters should be thoroughly cleaned.

Care must be taken to reduce normal brine shrimp feeding when the water is being treated with copper. At Steinhart Aquarium heavy mortality has often occurred among small fishes after they have gorged themselves with brine shrimp in copper-treated water (Herald and Dempster, 1965).

When this therapy is to be initiated, copper tests should be made twice daily during the period of copper sulfate addition. Once the concentration of the water system is adjusted, sequestered copper must be slowly added at a rate sufficient to maintain the concentration.[2]

After the desired therapeutic concentration has been established and the copper concentration is being maintained, daily tests are sufficient. Copper tests may be made by a standard colorimetric method (Snell and Snell, 1954, pp. 107–112). This method utilizes sodium diethyldithiocarbamate as a chromagenic

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[2] Grams of copper sulfate to produce a desired copper concentration may be obtained by the following:

$$CuSO_4 \cdot 5H_2O = \frac{V \times 14.875 \times PPM}{1000}$$

V = Total water volume in gallons.
PPM = Desired copper concentration.
14.875 = A constant.

agent. As can be seen in figure 1, copper has a broad absorption peak in the visible region, making measurements possible at 437 ± 3 millimicrons. Of the metals that form complexes with the reagent, iron and nickel are the only ones probable in an aquarium system. The iron interference is eliminated by the use of the citrate buffer. Figure 1 clearly shows that very large amounts of nickel must be present to cause an error in the copper determination, since its absorbence in the region of measurement is negligible. Hence sublethal concentrations can be ignored. The details of the procedure used at the Steinhart Aquarium are given below.

Necessary reagents:

Sodium diethyldithiocarbamate, reagent grade.

Copper-free water (double distilled from an all-glass still or de-ionized).

Ammonium hydroxide, concentrated reagent grade.

Ammonium hydroxide, 10 percent.

Carbon tetrachloride, reagent grade.

Citric acid, reagent grade.

Copper sulfate pentahydrate, reagent grade.

Reagent preparation:

Dissolve 1 gm. of $N(C_2H_5)_2\ CS_2Na$ in 100 ml. of copper-free water and add 10 percent NH_4OH until the pH reaches 9.6–10 (2 or 3 drops are sufficient).

Store in a bottle of dark glass protected from sunlight.

The indicator treated thus will remain stable for approximately 40 days.

Copper standard solution: Dissolve 0.393 gms. of reagent grade $CuSO_4 \cdot 5H_2O$ in 1 liter of copper-free water. Dilute 10 ml. to 1000 ml. One ml. of this solution contains 0.001 mg. of copper.

Ammonium citrate buffer 20 percent: Dissolve 200 gms. citric acid in approximately 500 ml. of copper-free water.

Add concentrated ammonium hydroxide until the pH reaches 9–9.2 (approx. 240 ml.). Add copper-free water to 1000 ml.

Procedure. Obtain a 100 ml. water sample. Transfer the sample to a separatory funnel, add 5 ml. of ammonium citrate buffer, and mix. Add 1 ml. of sodium diethyldithiocarbamate indicator and mix again. The carbamate, when introduced into the water sample containing copper, produces an amber color. The intensity of this color is proportional to the amount of copper present. After the liquid in the funnel is thoroughly mixed, 10 ml. of carbon tetrachloride is added and the sample is shaken for 2 minutes to extract the copper. In order to achieve complete phase separation the solution must be allowed to stand for 10 minutes. The colored layer is then drained off into a test tube and read in the colorimeter at a wave length of 437 ± 3 millimicrons against an appropriate blank.

A working curve is constructed by analyzing known amounts of copper and

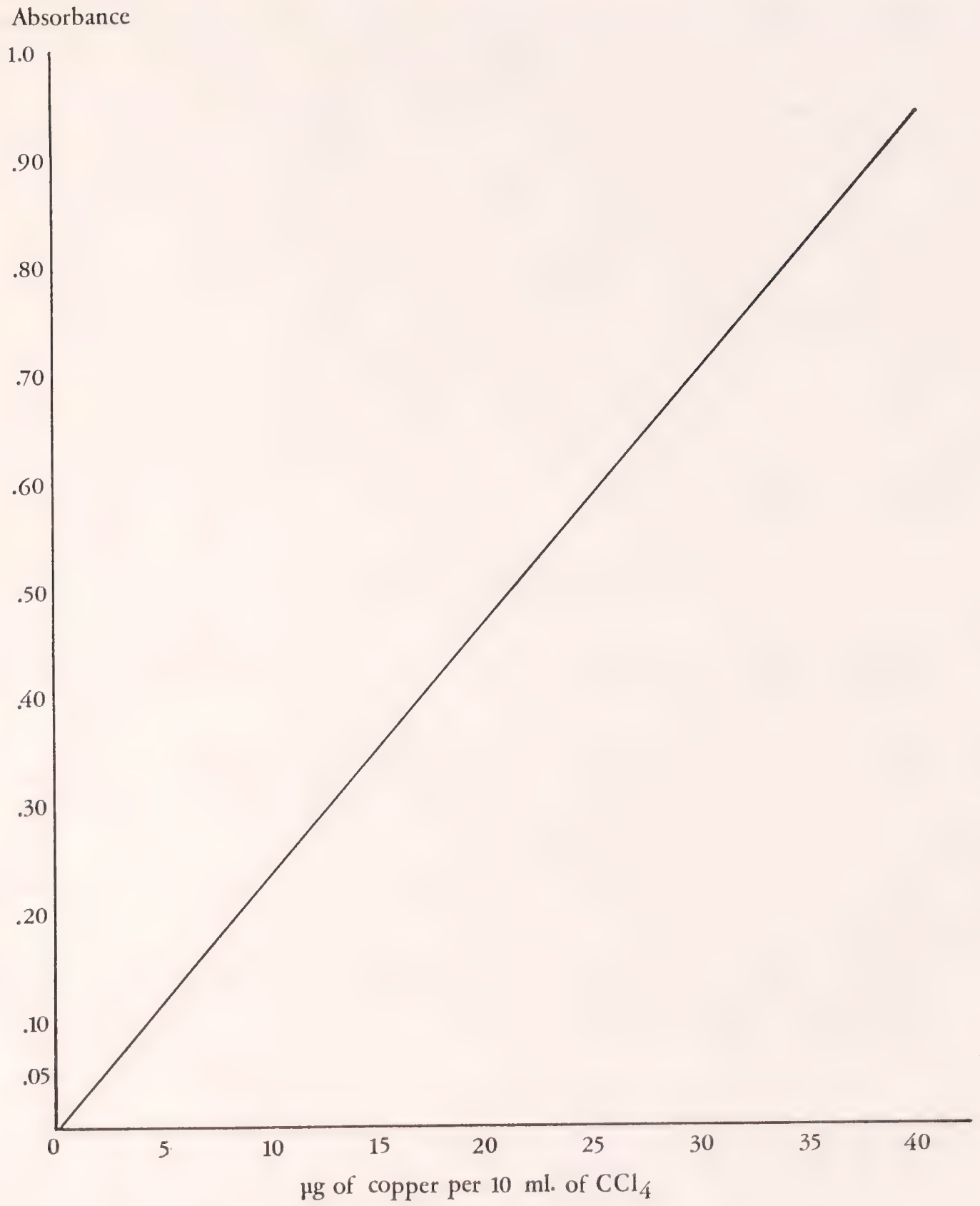

FIGURE 2. Graph for determining copper concentrations in known volumes of water. Absorbance $= 0.023$ (μg Cu) $+ 0.005$, μg Cu $= (A - 0.005)/0.023$. The equation of best fit was derived by linear regression.

plotting absorbance (optical density) as the ordinate and micrograms of copper as the abscissa (fig. 2). The line of best fit can be derived by linear regression.

It has been our experience that Beer's law is obeyed over the range of 5 to 40 micrograms copper in 10 ml. of carbon tetrachloride; therefore, the amount of water sampled must be of sufficient volume to contain copper in these amounts.[3] In order to maintain a constant extraction volume in all samples, the total volume of each sample should be increased to 100 ml. with copper-free water before it is processed.

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[3] To convert weights versus volume to ppm. of copper use the following equation:

$$\text{ppm. Cu} = \frac{\text{micrograms Cu}}{\text{ml. water sample}}$$

For the past 15 years copper sulfate has been periodically added to the tropical sea water system at Steinhart Aquarium and as a consequence there has been no epizootic outbreak of disease among the fish in this system since the *Oodinium* attack in 1951. The development of the copper treatment technique has been a boon to the aquarium world. Many of the reef fishes that ordinarily succumb to diseases that attack them when they are kept in captivity, are maintained for long periods in good health as a result of a working knowledge of this technique. Maintaining copper concentrations ranging up to 1 ppm. has been an asset to the marine mammal display at the Aquarium. Concentrations at this level have served as a deterrent to the growth of algae in the water circulating through this water system, and as far as is known copper in this concentration has no ill effect on the animals.

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OCCASIONAL PAPERS

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California Academy of Sciences

No. 72, 6 pages, 4 figures. June 6, 1969

Pyrgupyxis, a New Genus of Diatoms from a South Atlantic Eocene Core

By

N. Ingram Hendey

St. Agnes, Cornwall, England

SAN FRANCISCO

PUBLISHED BY THE ACADEMY

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By
N. Ingram Hendey
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In a recent study of some material from a core taken in the South Atlantic Ocean, many siliceous organisms usually referred to the genus *Pyxilla* were found. The age of the material is Eocene. The core is one of a series taken by personnel of the R. V. *Vema* on a survey organized and directed by Dr. Maurice Ewing, Director, Lamont Geological Observatory of Columbia University.

The pertinent locality information follows:

Cruise	Core	Depth Meters	Latitude	Longitude	Length of Core	CAS Number
V 18	112	2429	51°40′S.	48°29′W.	260 cm.	41054

The lower portion of the core, 96–260 cm. was described as follows: "Yellowish-gray (5Y7/2) moderately sorted, diatomaceous, slightly silty lutite mixed with about 5–7 percent minerals and rock fragments. The lutite contains diatoms and sponge spicules, as the major constituents and a minor amount of Radiolaria."

The genus *Pyxilla* was established by Greville (1865) with the following description: "*Pyxilla*, n. gen. Grev. Frustules free, oblong, transversely bivalved, box-like, minutely cellulate; each valve terminating in a short, thick apiculus." Two species were described, *Pyxilla johnsoniana* and *Pyxilla barbadensis* Greville (1865, p. 2), and illustrated on plate 1, figures 6 and 5.

Greville's type specimens are now in the British Museum, *P. johnsoniana* B.M. 2771 and *P. barbadensis* B.M. 3037 and an examination of them showed that they are complete cells exactly as illustrated by Greville and that his comment that "the globose valve with it's contracted base and terminal apiculus resembles the bulbous dome which crowns the minaret of an eastern mosque" is a reasonably accurate description. *Pyxilla* Greville is therefore seen to be sym-

metrical upon the apical axis consisting of two parts *each* furnished with a central projection. In the following remarks the two elements of which the cell is composed will be referred to as "parts" not valves, as the latter term has a specific meaning with reference to diatoms. Greville's material came from the Cambridge estate Barbados. The type slide B.M. 2771 has only one specimen of *P. johnsoniana*; fortunately it is a whole cell and no other fragments of *Pyxilla* are present, though the preparation is a "strewn" slide and contains a large number of other species. The same remarks apply also to slide B.M. 3037.

The specimens found in core V18–112 are of a totally different structure. The South Atlantic core contains a large number of specimens like those referred to *Pyxilla* by Forti (1909) as *P. johnsoniana* and *P. gracilis*. Forti's interpretation of *Pyxilla* has been followed by all authors who have described similar specimens. For convenience the bipartite specimens from core V18–112 are considered to consist of a short cylindrical cuplike element that will be referred to as the lower part and a funnel or trumpet-shaped component that will be referred to as the upper part. The upper part serves as a lid to the cuplike lower element, it is circular in the transapical plane with a convex surface and has its center drawn out to form the hornlike projection that resembles the stem of the funnel. This hornlike projection, usually curved, often increases in width shortly after leaving the surface of the upper part, but narrows again towards the top which is furnished with one or two small apiculi. On the side of the hornlike extension of the upper part is a notch or spur which is the point of attachment of the adjacent cell. The whole cell is punctate–areolate; the upper part being more coarsely marked. The circular face of the lower part is often slightly recessed around the margin and the areolae are larger towards the margin decreasing in size as they reach the center. In the center the areolae may cover the entire area or may break down to form a few scattered puncta, one or two of which might appear to be more prominent than the others. The puncta are arranged in radiating lines, though in some cells the lower face may show two centers which tend to complicate the radial arrangement. There is no structure present that corresponds to a girdle in the normal diatom, but often there is a slight constriction showing a hyaline line where the two parts join.

Often the cells are found joined together in pairs and from the mode of attachment of similar ends, that is, funnel end to funnel end, it is usually accepted that the cell is a resting spore of a diatom. It is not known for certain which species of diatom produces a particular type of bipartite cell, but frequently cells are seen with "fragments" of a thin tubular investment attached which is finely punctate and probably belongs to a *Rhizosolenia* species.

It is not known whether *Pyxilla* Greville formed pairs as the type slide shows only a solitary specimen, but it is likely that it did not, as no notch or scar of attachment is visible on the short extension of the upper part of the type speci-

men. In the South Atlantic material many whole cells were found though most occurred as separated parts.

It is clear that as the lower part of the South Atlantic specimen does not possess an apiculus or extension, and the upper part with its long hornlike extension, usually curved, and bearing a marginal spur (attachment scar), is so unlike Greville's species, the V18–112 cells cannot be referred to *Pyxilla*, as Greville's description excludes them. It is proposed therefore that the new genus *Pyrgupyxis* be established to accommodate the specimens from the core together with similar species which, until now, have been erroneously placed in *Pyxilla*.

Pyrgupyxis Hendey, new genus

Cellula cylindricalis, parté supera infundibuliformis et apiculis terminalibus instructá. Pars infera, brevis cylindricalis, cupulata. Superficies valvarum areolata. Cellulae in paribus extremis similibus conjunctae.

Cell cylindrical, with the upper part shaped like a funnel and furnished with terminal spines. Lower part short, cylindrical, cuplike. Surface of the parts areolate. Cells united in pairs by similar ends.

Pyrgus—a tower, *pyxis*—a box.

Pyrgupyxis eocena Hendey, new species.

(Figures 1–4)

Cellula cylindricalis, in daubus partibus formata. Pars supera ad instar infundibuli et apiculis terminalibus instructa. Pars infera brevis cylindricalis, cupulata. Superfies partium areolata, areolae in parte infera in striis radiantibus dispositae.

Mensura cellularum: Long. 70–80 microns; lat. 35–40 microns. Hab. In medio ex solo maris in Oceano Atlantico.

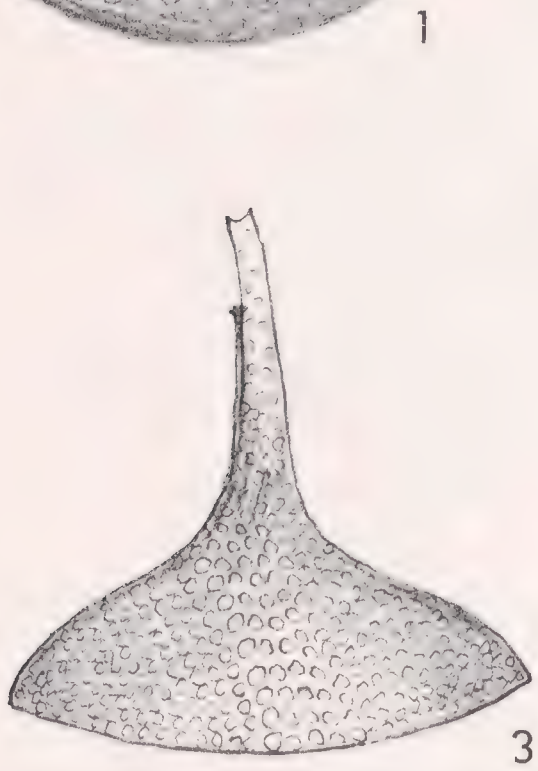
Cell cylindrical. Formed in two parts. Upper part in the form of a funnel and furnished with terminal spines. Lower part short cylindrical, cuplike. Surface of the parts areolate, areolae on the lower part arranged in radiating striae.

Dimensions of the cells length 70–80 microns, breadth 35–40 microns.

Habitat. In a core from the sea floor in the Atlantic Ocean.

Holotype no. 3959 (CAS) from Locality 41054, lat. 51°40′S.; long. 48° 29′W.; Lamont Geological Observatory no. R. V. *Vema* Cruise 18, core 112, depth 2429 M. Eocene. The Eocene age has been readily determined by comparison of other species of diatoms and Silicoflagellata associated with this *Pyrgupyxis* at such well known localities as Barbados, West Indies, Oamaru, New Zealand, Mors Denmark, and Kreyenhagen Shale of California.

The lower cuplike portion of the diatom has a deep mantle with straight sides and the areolae are in quinquux.



FIGURES 1–4. *Pyrgupyxis eocena* Hendey, new genus, new species. Approximate magnification, ×1000.

The lower surface is convex and slightly invaginated at the margin. The surface is punctate–areolate, with the areolae larger at the margin than at the center which may be entirely areolate or the areolae may be reduced to a few scattered puncta. The upper part is convex, with no definite mantle at the margin, and the center is drawn out or produced to form a hornlike structure, usually slightly curved, and bearing a notch or spur on one side which is the point of attachment of the contiguous cell. The upper part is like a funnel where the stem of the funnel is about the same length as the diameter of the wider cuplike end. The distal end of the upper part usually carries two small terminal apiculi. The surface of the upper part is areolate with the areolae larger at the broader end and reduced in size as they proceed up the produced or stemlike

portion, at the distal end of which the puncta are few and small. The diameter of the lower cuplike end is greater than the depth of the cup.

Pyrgupyxis eocena was common in the V18–112 material.

Other described species of *Pyrgupyxis* include the following:

Pyrgupyxis johnsoniana = *Pyxilla johnsoniana* in Forti (1909), non *Pyxilla johnsoniana* Greville (1865).

Pyrgupyxis johnsoniana var. *intermedia* = *Pyxilla johnsoniana* var. *intermedia* Tempère et Forti in Forti (1909).

Pyrgupyxis gracilis = *Pyxilla gracilis* Tempère et Forti in Forti (1909).

Pyrgupyxis gracilis var. *buccinalis* = *Pyxilla gracilis* var. *buccinalis* Forti in Forti (1909).

Pyrgupyxis gracilis var. *saratoviana* = *Pyxilla gracilis* var. *saratoviana* Tempère et Forti in Forti (1909).

Pyrgupyxis caput–avis = *Pyxilla Caput–Avis* J. Brun in Forti (1909).

Pyrgupyxis caput–avis var. *gracilis* = *Pyxilla Caput–Avis* var. *gracilis* Tempère in Forti (1909).

Pyrgupyxis prolongata (J. Brun) = *Pyxilla prolongata* J. Brun in Forti (1909).

Other species of *Pyrgupyxis* from the V18–112 and other cores are being studied.

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No. 73, 4 pages, 1 figure. June 6, 1969

A New Pipefish from the Virgin Islands, *Micrognathus dawsoni*

By

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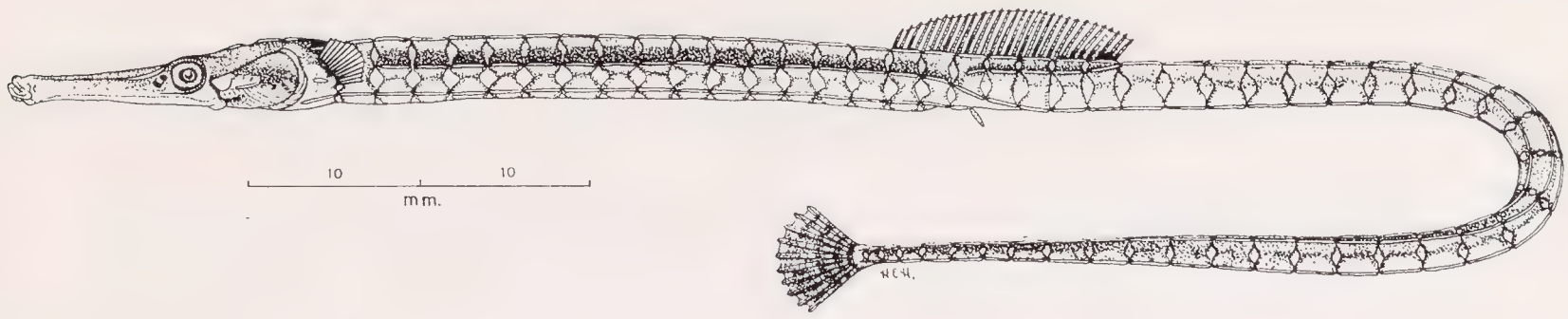
Twenty-five species of Atlantic American pipefishes have previously been recognized (Herald, 1965), and the addition of an intriguing new species from St. John brings the total to 26. It can be expected that deepwater pipefishes will be discovered in the future, but it is quite startling that this shallow water form should have escaped notice until this time.

The syngnathid genus *Micrognathus* is one of the intermediates on the evolutionary line believed to lead from the *Parasyngnathus*-type pipefishes with everted brood pouch closure (E-BPC) to the *Hippocampus*-type seahorse (Herald, 1959). There are 12 species in *Micrognathus*, four in the Atlantic including the new one described herein, and eight in the Pacific. Two subgenera are recognized: *Anarchopterus* Hubbs with only two species, both Atlantic, has smooth body ridges and lacks the anal fin. The subgenus *Micrognathus* Duncker with two Atlantic and eight Pacific species has sharp body ridges and does have the anal fin.

Micrognathus (Micrognathus) dawsoni Herald, new species.

Holotype. USNM 203148, female 134.5 mm. standard length (139 mm. total length); Fish Bay, St. John, U.S.V.I.; depth 5 feet, sand bottom with some *Thalassia* and scattered algae. Chemfish ichthyocide; 16 November 1966. C. E. Dawson and A. Damman, collectors.

Diagnosis. Dorsal fin rays 30; pectoral 13–13; anal 3; caudal 10; dorsal fin covering 7 rings: 2½ trunk rings and ½4 tail rings; trunk rings 17½; tail rings ½35 (see discussion below); snout 9.2 mm.; head 16.9 mm.; dorsal fin base 12.9 mm.; trunk 39.6 mm.; tail 78.0 mm.; pectoral base 1.7



Micrognathus dawsoni Herald, Holotype, USNM 203148,
139 mm female; Fish Bay, St. John, U.S.V.I.

FIGURE 1. *Micrognathus dawsoni* Herald, new species.

mm.; pectoral length 2.3 mm.; head-in-standard length 7.95; snout-in-head 1.84; dorsal fin-base-in head 1.31; head-in-dorsal fin base 0.76; brood pouch details unknown; body ridge pattern typical of *Micrognathus, i.e.,* lateral trunk ridge deflected ventrally at anal ring, then continuous with inferior tail ridge; superior tail ridge deflected ventrally at dorsal fin becoming lateral tail ridge, and ending free at anal ring. Belly flat. Color: light tan; slightly darker above lateral trunk ridge; scutella dark-rimmed; caudal dark.

DESCRIPTION. Median snout ridge smooth, beginning at interorbital area and extending forward one-half length of snout. Superior ocular ridge extends forward for one-half eye diameter, and posteriorly one-third of an eye diameter. Mid opercular ridge equal to one-third length of opercle. Pectoral cover plate with distinct median ridge and indistinct superior ridge. Nuchal ridge tri-lobed. Body ridges well developed but without sharp edges.

COMPARISON. Among the eight species of Atlantic American pipefishes that have the lateral trunk ridge continuous with the inferior tail ridge, two species only, *i.e., Ichthyocampus pawneii* and *Penetopteryx nanus,* lack the lateral tail ridge. The remaining six species, including the four *Micrognathus,* have this ridge well developed. The seahorse pipefish, *Amphelikturus dendriticus,* as well as the true seahorses, *Hippocampus* species, can be identified by their prehensile tails. *Oostethus* and *Micrognathus* may be separated by the short tail of the former with number of rings being only 4–7 more than number of trunk rings; by contrast, *Micrognathus* has about twice as many tail rings as trunk rings. *Micrognathus dawsoni* has 30 dorsal fin rays, whereas the other three Atlantic American members of the genus have only 16–22 dorsal rays.

COMMENTS. In most pipefishes, the normal position of the anus is at the posterior end of the last trunk ring with the anal fin on the anterior end of the first tail ring. This relationship does not hold for *M. dawsoni,* since the anus is far enough forward on the anal ring so that there is room for the anal fin on the posterior portion of the ring. Hence to be thoroughly accurate in the ring counts they should be shown as 17½ + ½35. This could be interpreted as 18 + 35 or 17 + 36; the writer prefers the latter.

Named in honor of C. E. Dawson, who collected and recognized this pipefish as different from the other Atlantic syngnathids.

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No. 74, 8 pages, 23 figures. June 6, 1969

Additional Records of *Tetrabalanus polygenus* Cornwall, 1941 (Cirripedia, Thoracica)

By

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ABSTRACT: The four-plated balanid barnacle *Tetrabalanus polygenus* Cornwall, 1941, unreported since its original description from Puna Island, Gulf of Guayaquil, Ecuador, is recorded from the Guayas River estuary at Guayaquil, Ecuador, Santa Elena Bay, Ecuador, and Puntarenas, Costa Rica. The latter occurrence increases the known range of this monotypic genus over 12.5° of latitude to the north, and suggests a wide distribution for the species in the Panamic Province. Although capable of living in waters of normal marine salinities, *Tetrabalanus polygenus* appears to prefer estuarine conditions commonly associated with typical mangrove facies.

INTRODUCTION

The unusual porose-walled, four-plated balanid *Tetrabalanus polygenus* Cornwall, 1941 has not been reported since its original description from shore localities on Puna Island in the Gulf of Guayaquil, Ecuador. Four additional lots have now been uncovered that provide supplementary data on morphology, geographic distribution, and ecology of this species.

The first lot to come to my attention was obtained by Mr. Robert Schuster, University of California at Davis, on 5 March 1964 during the 1964 Galápagos International Scientific Project. Six large individuals were taken from a moderately dense population at mid-tide on dock pilings at Porto Nuevo, Guayaquil in the Guayas River estuary (California Academy of Sciences (CAS) locality 40748). Two additional lots were uncovered in the following year at the Academy of Natural Sciences of Philadelphia (ANSP). One, consisting of four specimens from Santa Elena Bay, Ecuador, had been donated by Herbert N. Lowe in 1933 (ANSP cat. no. 2602). The second, of six individuals, was taken on the oyster *Ostrea* (*Crassostrea*) *columbiensis* Hanley, 1846, attached to mangroves on the mud flats along the Estero at Puntarenas, Costa Rica, by George

and Mary Kline in January, 1966 (ANSP catalog number 7302). A fourth lot of over 50 specimens was found on two shells of *Ostrea columbiensis* in the collection of the California Academy of Sciences (CAS locality 28027). The oysters, from mangrove roots in Santa Elena Bay, Ecuador, were donated by Herbert Lowe in 1934, and probably represent the same collection as that of ANSP catalog number 2602.

Morphology

Shell (figs. 5–6, 11–12). Many of the specimens on hand are larger than those of the type lot. The largest, from the dock at Guayaquil, is 24 millimeters in carinorostral diameter, and most of the others from that locality are 20 millimeters in diameter, or at least twice the diameter of the largest type lot individual. A conspicuous yellow to dirty-brown epidermis covers at least the lower half of the shell in most specimens. The radii vary somewhat in width, but always have steeply oblique summits and thick sutural edges whose septa are denticulate on their lower sides. The alae are short with gently sloping summits that project above the radii. The sheath is short, but usually hangs free, leaving a space under its lower edge. The numerous parietal tubes are square to rectangular in outline when viewed basally, tend to be filled in their upper parts, and are crossed by transverse septa for most of their remaining length. The basal edge of the outer lamella of the shell wall bears minute, regularly spaced denticulae and, usually, one to three large secondary septa that project into the parietal tubes, but do not reach the inner lamella. These secondary septa are denticulate basally and form part of the articulation between shell wall and basis.

Scuta (figs. 1, 3, 8, 9). The exterior of the scutum is concave between basal margin and apex, and is covered with a thick, yellow-brown epidermis. Underneath, the scutum is tricolored, with a broad central band of purple-pink flanked by narrow white stripes on the occludent and tergal margins. The growth lines are irregular, but not prominent and are crossed by faint radial striations. The articular ridge is short, being roughly half the length of the valve, but quite prominent and reflexed over the deep articular furrow. The prominent adductor ridge is short, centrally located on the valve, and parallel to the occludent margin. It overhangs a large, deep, triangular pit that extends

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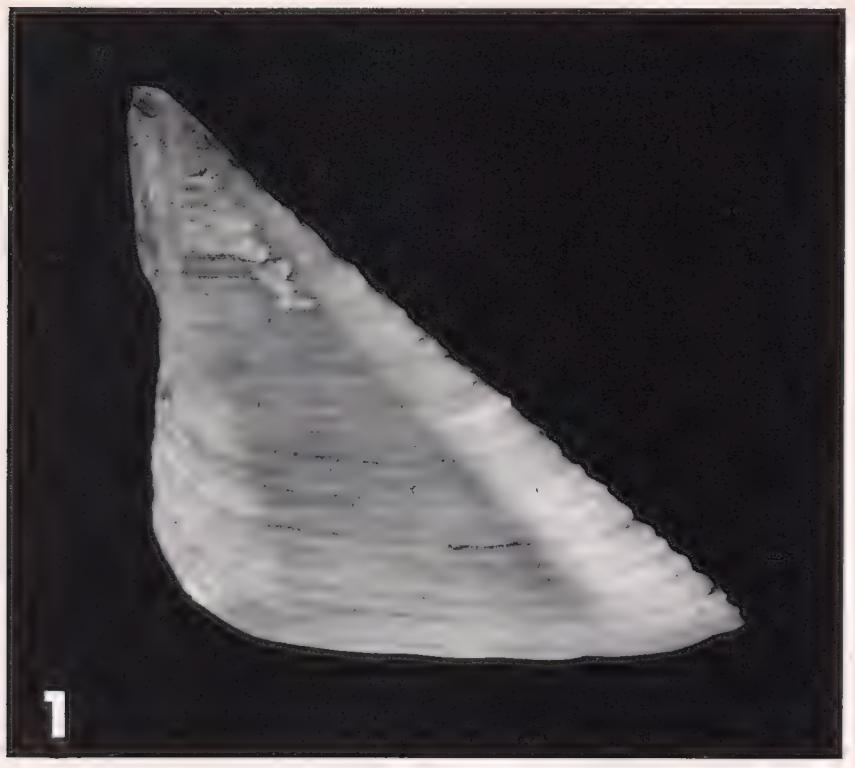
Figures 1–4. Opercular valves of *Tetrabalanus polygenus* Cornwall, hypotype CAS 13148, CAS locality 40824, Ecuador. Figure 1, exterior of scutum showing color pattern, height 6 mm.; figure 2, exterior of tergum, height 5.6 mm.; figure 3, interior of scutum, height 6 mm.; figure 4, interior of tergum, height 5.6 mm.

Figures 5, 6. Shells of *Tetrabalanus polygenus* Cornwall, CAS locality 40824, Ecuador. Figure 5, basal view showing details of septation, hypotype CAS 13152, greatest diameter of base 21 mm.; figure 6, rostrum with outer lamella removed to show transverse septa of parietal tubes, hypotype CAS 13151, greatest width of plate 15 mm.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upward beneath the arch formed by the confluence of the upper end of the adductor and the lower end of the articular ridges. The adductor pit is large and deep. In young specimens there is little or no indication of a lateral depressor muscle pit, but in larger ones a small shallow pit is found at the basiscutal angle. In all specimens examined, a low ridge extends from the base of the articular ridge along the occludent border of the lateral depressor muscle pit area to the basal margin, forming an elongate triangular hollow between it and the reflexed tergal margin of the valve. The apical part of the interior of the scutum is conspicuously roughened and ridged.

Terga (figs. 2, 4, 7, 10). The exterior of the tergum also has a thick epidermal covering. The cleaned valve is white with a suffusion of pink on the carinal half. The spur furrow is open throughout its length, but well marked by grooves on either side. The tergal spur is about one-fifth the height of the valve and occupies one-fourth to a little less than one-third the basal margin. It is rounded basally and placed close to the basiscutal angle. The articular ridge is low and erect and does not curve basally towards the scutal margin. The articular furrow is correspondingly shallow and broad. Lateral depressor muscle crests are numerous and prominent and project below the basal margin of the valve. The carinal side of the interior of the tergum is roughened and ridged.

Mouthparts (figs. 13–18). Two individuals, one from Guayaquil (CAS locality 40748) and the other from Puntarenas (ANSP cat. no. 7302) were dissected for comparison with the type description. The labra are deeply notched and the number of teeth on the crest is variable. The Puntarenas specimen has three on either side, whereas that from Guayaquil has two on the right and none on the left. The mandibles have three large upper teeth, the second being bifid, and two smaller molariform teeth below. The superior and inferior margins are setose. The first maxillae have straight margins except for the lower third which is slightly protrudent. There is no notch below the two large upper spines. The central third bears seven or eight slender spines, followed on the protrudent third by two large spines and several short spinules at the inferior angle. The superior and inferior margins are setose. The second maxillae are ovate, bilobed, and densely setose.

Cirri (figs. 19–23). The outer (anterior) ramus of cirrus I is antenniform and at least half again as long as the inner ramus. The lower articles of the

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Figures 7–10. Opercular valves of *Tetrabalanus polygenus* Cornwall, ANSP cat. no. 7302, Costa Rica. Figure 7, interior of tergum, height 5.5 mm.; figure 8, interior of scutum, height 6 mm.; figure 9, exterior of scutum, height 6 mm.; figure 10, exterior of tergum, height 5.5 mm.

Figures 11, 12. Shells of *Tetrabalanus polygenus* Cornwall. Figure 11, group of shells on *Ostrea columbiensis* Hanley showing epidermis, hypotype Lot CAS 13149, CAS locality 28027, Ecuador, length of oyster 56 mm.; figure 12, dorsal view of largest shell, hypotype CAS 13150, CAS locality 40824, Ecuador, carinorostral diameter 24 mm.

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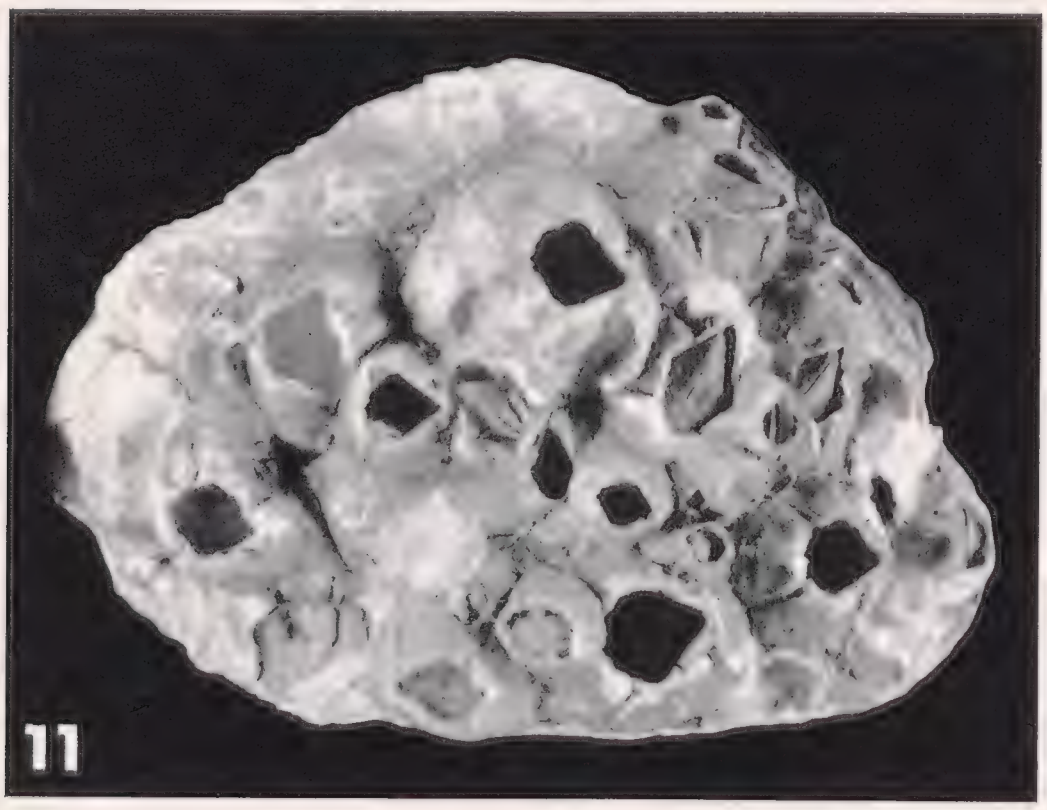
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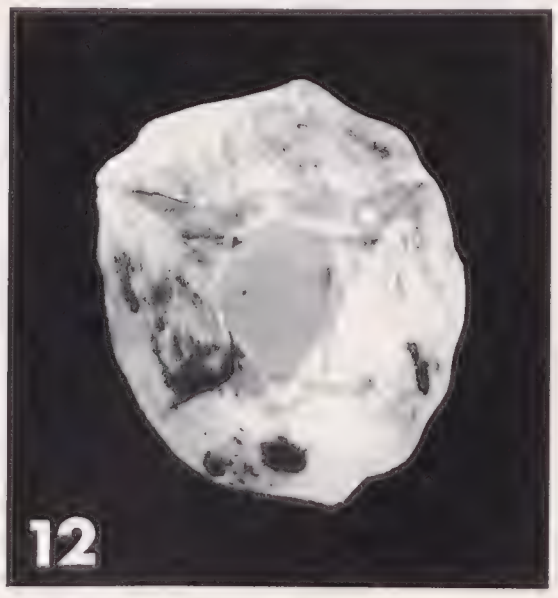
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inner ramus are protuberant and densely setose, whereas the distal articles are sparsely setose and attenuate. The rami of cirrus II are short, broad, of nearly equal length, and have densely setose, protuberant articles. The nearly equal rami of cirrus III are short, but longer and more slender than those of cirrus II, and without protuberant articles. The articles of the lower half of each ramus bear numerous small teeth scattered over their anterior faces, and one to four upwardly recurved teeth near the distal posterior edge. Cirri IV–VI are slender and elongate, and the articles of the lower half of each ramus bear a single upwardly recurved tooth at the distal posterior edge. The median articles of cirrus VI have up to seven pairs of spines.

Ecology and Distribution

Although salinity data for the localities described herein were not available to me, the records suggest that *T. polygenus* is a euryhaline species that may prefer brackish environments. With the exception of the type lot from shore rocks in apparently marine waters, all localities indicate lowered salinity conditions for at least part of the year. The Guayas River locality is 48 kilometers from the sea, and the Santa Elena and Puntarenas specimens appear to be associated with typical brackish mangrove facies.

The presumed brackish water representatives of this species differ from the type lot in their larger average size and in their possession of an epidermal covering. Parallel situations can be found in other euryhaline species such as *Balanus eburneus* Gould, 1841, and *B. improvisus* Darwin, 1854, on the East Coast of North America. Individuals living in estuaries (15–20‰) attain greater average size and possess a more conspicuous epidermis than do those in normal marine environments (30–34‰). This greater development of epidermis may be a response to the effects of lowered pH in brackish water on shell dissolution.

The occurrence of *Tetrabalanus polygenus* at Puntarenas, Costa Rica, increases the known range of this species over 12.5° of latitude to the north, and suggests that it is widely distributed in the Panamic Province. Although the barnacles of this province are poorly known, it is unusual that more specimens of *T. polygenus* have not been encountered in museum collections. If, however, this species is usually associated with brackish mangrove facies, its absence in collections is more easily understood, as most marine invertebrate collecting in the Panamic Province has been directed at the normal marine environment.

→

Figures 13–19. Mouth parts and Cirrus II of *Tetrabalanus polygenus* Cornwall. Figure 13, mandible; figure 17, labrum; figure 19, Cirrus II, hypotype CAS 13148, CAS locality 40824, Ecuador, × 30. Figure 14, mandible, × 30; figures 15, 16, maxilla I, × 45; figure 18, labrum, × 30, ANSP cat. no. 7302, Costa Rica.
(Prints by G Dallas Hanna)

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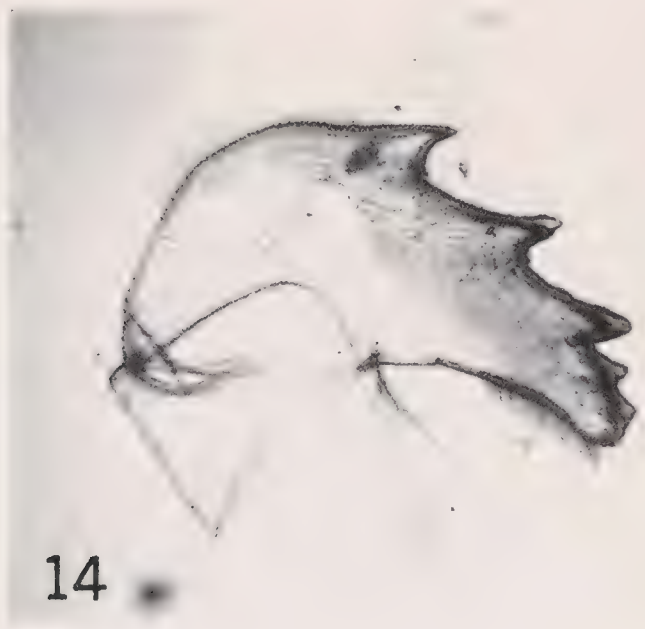
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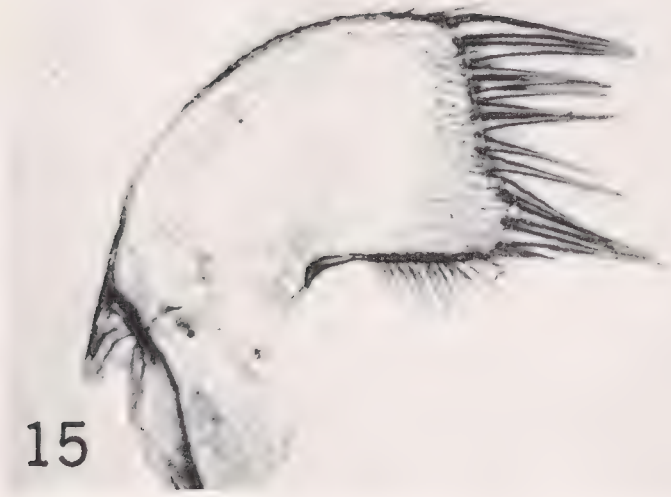
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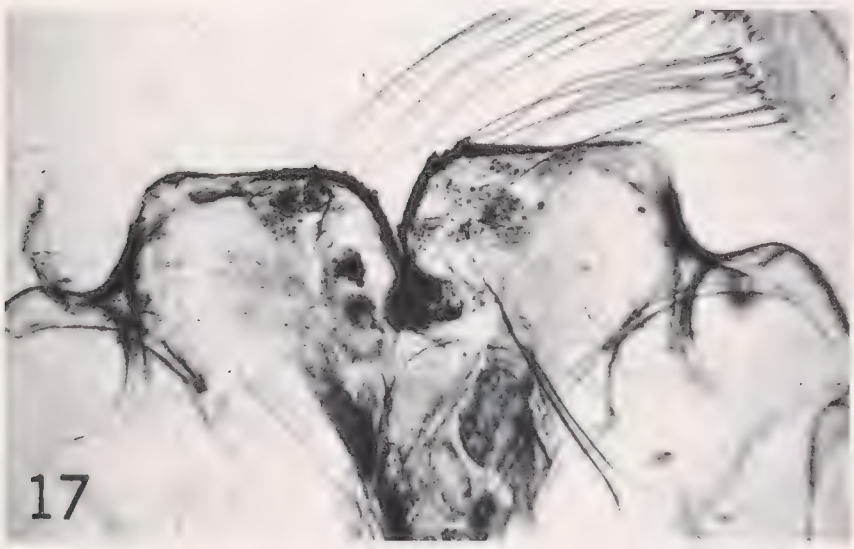
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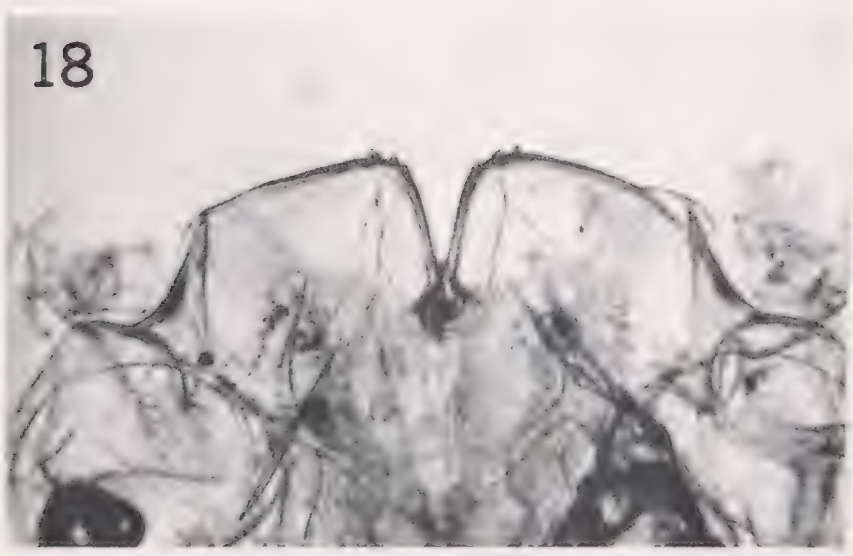
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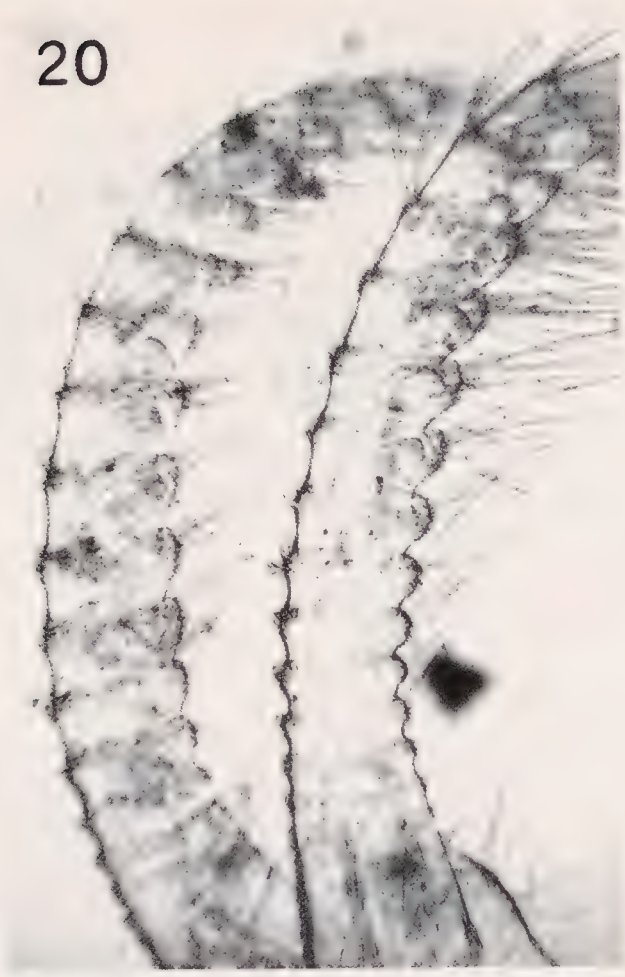

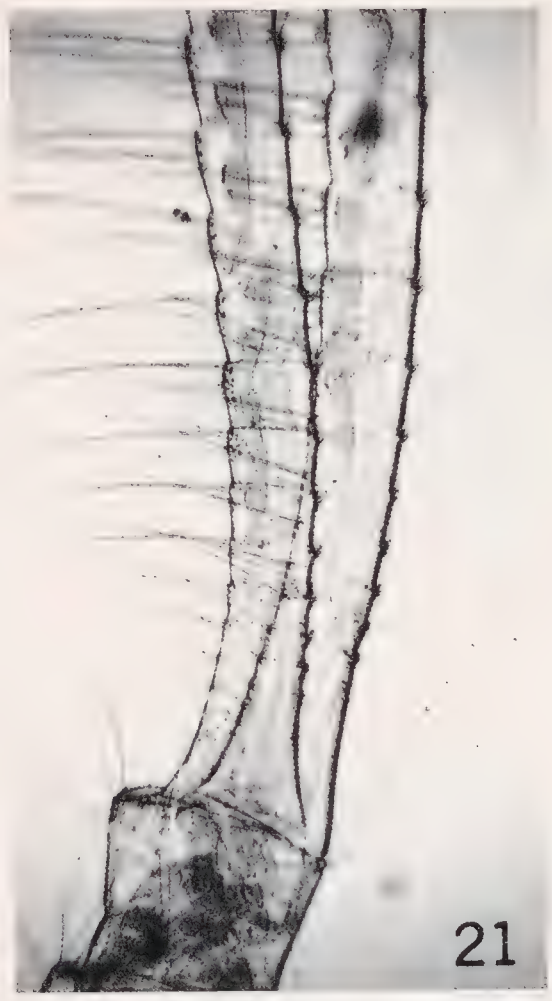

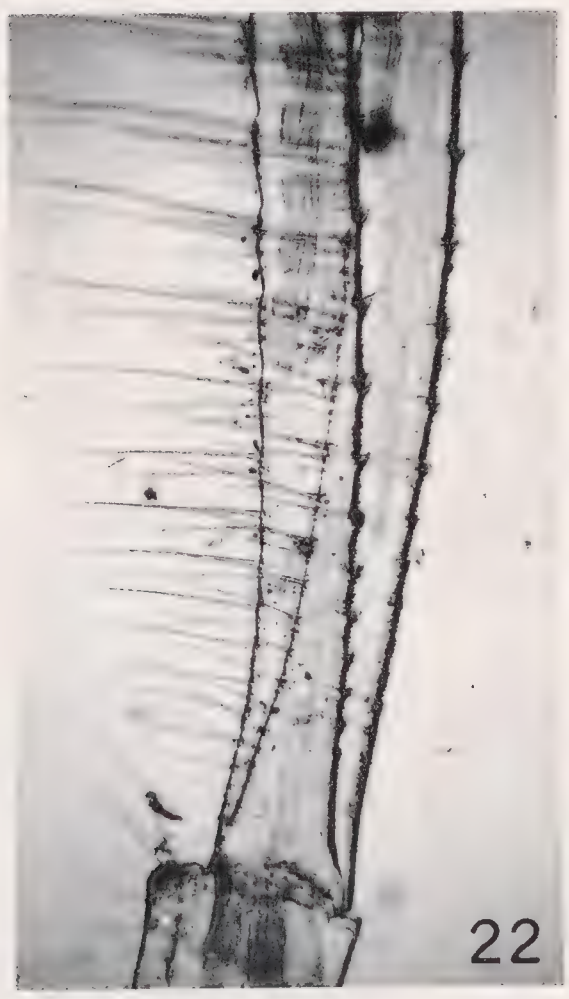

Figures 20–23. Details of cirri of *Tetrabalanus polygenus* Cornwall, × 30. Figure 20, Cirrus III; figure 21, Cirrus IV; figure 22, Cirrus V, hypotype CAS 13148, CAS locality 40824, Ecuador. Figure 23, Cirrus VI, ANSP cat. no. 7302, Costa Rica.
(Prints by G Dallas Hanna)

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California Academy of Sciences

No. 75, 6 pages, 2 tables. October 22, 1969

Early Records of the Barnacle *Balanus improvisus* Darwin from the Pacific Coast of North America

By

James T. Carlton and Victor A. Zullo

California Academy of Sciences, San Francisco, California 94118

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Balanus improvisus Darwin is commonly encountered in the Atlantic and Caribbean littoral, and has been reported from various localities in the Mediterranean, Red Sea, and Indian Ocean. Although a euryhaline species, it is usually found in estuarine environments in association with oysters and other molluscs tolerant of lowered salinities.

The distribution of *B. improvisus* in the Pacific Ocean is spotty, however, and is considered to be the result of human introduction (Kawahara, 1963; Matsui and others, 1964; Newman, 1967). This species was first reported from the Pacific Coast of North America by Rogers (1939) who discovered it in San Francisco Bay, California (see Henry, 1942, table; 1959, p. 200). Since 1939, *B. improvisus* has been reported from Tomales Bay, Marin County, and the Salinas River estuary, Monterey County, both in California, and from the Columbia River in Oregon, these in addition to further records from greater San Francisco Bay (table 1). At present this species is well established in estuarine parts of San Francisco Bay and occurs up into rivers and creeks feeding the Bay, where salinities are negligible for most of the year.

There is little doubt that *B. improvisus* was introduced by man to California. Examination of late Cenozoic barnacle faunas from numerous Pacific Coast localities, including a late Pleistocene oyster-barnacle assemblage at Rodeo, California (University of California Museum of Paleontology, Berkeley locality A-3150), has failed to uncover specimens of *B. improvisus*. Newman (1954) also noted the absence of this species in Indian mound material at Brooks Island, San Francisco Bay, although *B. glandula* Darwin was common on mollusc shells now frequented by *B. improvisus*.

Table 1. *Records of* Balanus improvisus *from the Pacific Coast in the literature (1939–1968).*

Date	Locality	Authority
1939	San Francisco Bay, including San Pablo Bay and upper reaches of Suisun Bay	Rogers (1939, 1949), Henry (1942, 1959)
1939	"Inlets to flood valves on naval vessels cruising on the east and west coasts of the United States"	Henry (1942)
1940–1942	Oakland estuary, San Francisco Bay	Graham and Gay (1945)
1952	Lake Merritt, Oakland, San Francisco Bay	Marchette (1953)
1952	San Pablo and Suisun Bays, (greater San Francisco Bay)	Filice (1954, 1959a, 1959b)
1953	San Francisco Bay; mouth of Salinas River, Monterey County	Newman (1954, 1967)
1957	Astoria, Oregon (Youngs Bay and Youngs River, lower Columbia River system), on crayfish, *Pacifastacus trowbridgii*	Miller (1965)
1959	Tomales Bay, Marin County	Johnson and Juskevice (1965)

The question remains, however, as to how and when this barnacle was introduced. *Balanus improvisus* is a common fouling barnacle on ships in the Atlantic Ocean, and San Francisco Bay has been a major port of call for vessels from the East Coast of North America since the gold rush of 1849. During the peak years of the California gold rush, ships not only docked in the Bay, but were abandoned by the hundreds, thus greatly increasing the probability of the successful establishment of barnacles.

A second method, resulting from the importation of the East Coast oyster, *Crassostrea virginica* (Gmelin), is an even more likely candidate (see Skinner, 1962; Barrett, 1963 for discussion of the West Coast oyster industry). Both seed and adults of this species are known to have been introduced into San Francisco Bay for purposes of culture as early as 1869. Prior to this time, and as early as 1849, attempts were made to market live oysters in San Francisco, but most of these did not survive the journey across the Isthmus of Panama. Eastern seed oysters were shipped by rail in terms of hundreds of carloads per year until 1910, but adults, which were often held in beds in San Francisco and Tomales Bays until sold, continued to be imported. *Balanus improvisus* is often encountered as an epizooite of *Crassostrea virginica*, and would stand at least an equal chance with the oysters of surviving rail transportation from the East Coast. Assuming that shipping and oyster importation could both provide the

TABLE 2. *Early records of* Balanus improvisus *on the Pacific Coast (prior to 1939).*

Date	Locality	Collector	Material
1853	UCMP 2394, San Francisco Bay	C. de Lange	2, on *Mytilus edulis* (Linnaeus)
1900	SU 21481, San Mateo, San Francisco Bay	E. E. Smith	1 live, 1 empty shell, on *Crassostrea virginica*
20 October 1903	CAS 41224, Cooley'sLanding, Alviso, Santa Clara County, San Francisco Bay	unknown	2, 1 on *Modiolus demissus* (Dillwyn)
1910–1915	SU 4651, Redwood City estuary San Francisco Bay	H. Hannibal	4, on *Mytilus edulis*
3 April 1912	CAS 41202, San Francisco Bay	E. C. Johnston (naturalist, *Albatross*)	2, on *Mytilus edulis*
27 November 1912	CAS 41200, *Albatross* Station D-5812B, south San Francisco Bay, 1 fathom	(see Packard, 1918, p. 207)	common (dead), on *Crassostrea virginica*
October, 1913	CAS 41201, Alameda, San Francisco Bay	"DSG"	9, on valve of live *Ostrea lurida* Carpenter
1 January 1922	CAS 41189, Oakland Mole, Oakland, San Francisco Bay	E. L. Lazier	3, from submerged timber 12 feet below low water
28 August 1922	CAS 41225, Dumbarton Bridge, south San Francisco Bay	(see Hill and Kofoid, 1927, loc. 57)	3, from pilings; 1 with 12 egg cases of *Urosalpinx cinerea* (Say)
1 August 1923	CAS 41190, Crockett, San Pablo Bay	(see Hill and Kofoid, 1927, loc. 6)	numerous, some on *Mytilus edulis,* from submerged timbers
September, 1931	CAS 27023, Rodeo, San Pablo Bay	G Dallas Hanna	1, on *Mytilus edulis*
24 March 1932	CAS 41226, San Pedro outer harbor, berth 59, opposite column 43	E. L. Lazier	numerous, on creosoted fender pile, 4 feet above low water
1934	SU 3814, Palo Alto Yacht Harbor, San Francisco Bay	Stanford Class	numerous, on *Ostrea lurida*
no date (locality registered in 1955)	UCMP B-1273, Willapa Bay, Washington	T. Kincaid	numerous, on *Crassostrea gigas* (Thunberg)

means for establishing *Balanus improvisus* in San Francisco Bay, it is probable that this barnacle was successfully introduced on numerous occasions.

In investigating the possibilities of introductions prior to 1939, a search was made of the following collections from San Francisco Bay and other Pacific Coast localities:

1) California Academy of Sciences (CAS)
   a) Recent dry mollusc collection, Department of Geology.
   b) Wet mollusc collection, Department of Invertebrate Zoology.
   c) *Albatross* dredgings from San Francisco Bay, 1912–1913.
   d) San Francisco Bay marine boring study samples, San Francisco Bay marine piling committee, 1920–1924.
2) University of California Museum of Paleontology, Berkeley (UCMP), recent mollusc collection.
3) Stanford University (SU), recent mollusc collection.
4) San Francisco Maritime Museum, artifact collection.

The results of this survey are presented in table 2. *Balanus improvisus* was discovered in 14 collections made between 1853 and 1934. All of the listed records are based on specimens having opercular valves. With the exception of the *Albatross* collection of 27 November 1912, the San Mateo collection of 1900, the Alviso collection of 20 October 1903, and the undated material from Willapa Bay, Washington, all of the barnacles were collected alive on either native molluscs or pilings, thus indicating at least temporarily successful establishment.

Balanus improvisus is represented in every decade of the twentieth century. The samples collected in 1903 from Alviso and 1913 from Alameda coincide closely with sites of commercial *Crassostrea* beds that were under cultivation prior to 1915 (Skinner, 1962, pl. 3). Only a single nineteenth century record was obtained. The lack of additional early material is in large part the result of the dearth of adequately dated and localized collections. However, the 1853 record based on C. de Lange's collection appears authentic, and is in keeping with our knowledge of his activities during the middle nineteenth century. As this record precedes oyster culture activities, it is possible that the specimens represent an early introduction by shipping.

In addition to the specimens from San Francisco Bay, a well documented lot collected in 1932 from San Pedro harbor, California and an undated series on *Crassostrea gigas* from Willapa Bay, Washington were uncovered. Whether *B. improvisus* presently occurs in these regions is not known.

Balanus amphitrite amphitrite Darwin (also known as *B. a. denticulata* Broch, *B. a. franciscanus* Rogers, *B. a. hawaiiensis* Broch, and *B. a. herzi* Rogers) is another introduced barnacle that is presently well established in San Francisco Bay and various localities in southern California. Rogers (1939) is also responsible for first noting its occurrence on the Pacific Coast. A search was made

for earlier occurrences of this barnacle as well, but no specimens were discovered.

The absence of *B. a. amphitrite* in earlier collections, if real, probably reflects its absence on the Atlantic Coast of North America prior to World War I, and perhaps as late as World War II (Zullo, 1966, pp. 233–235). Since its introduction to the East Coast, this barnacle has become a major element of the intertidal fauna south of Cape Hatteras, North Carolina and is often found on oysters in association with *B. improvisus*. Had it been available for transport from the East Coast, its history of introduction would probably have paralleled that of *B. improvisus*.

Acknowledgments

We wish to extend our thanks to Dr. Leo G. Hertlein and Dr. Robert C. Miller, California Academy of Sciences; Dr. A. Myra Keen, Stanford University; Mr. Joseph H. Peck, Jr., University of California, Berkeley; Dr. Edmund H. Smith, Pacific Marine Station, University of the Pacific; and Mr. Harlan Soeten, San Francisco Maritime Museum for their help in obtaining the materials used in this study.

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No. 76, 11 pages, 1 table, 1 figure. October 22, 1969

A New Scorpionfish of the Genus *Scorpaenodes* and *S. muciparus* (Alcock) from the Indian Ocean, with Comments on the Limits of the Genus

By

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ABSTRACT: *Scorpaenodes muciparus* (Alcock) and a new species, *S. tribulosus*, are described from the Indian Ocean. These two species occur in deeper water than do the other members of the genus. The genus *Scorpaenodes* is redefined to include the following nominal genera: *Sebastopsis* Gill, *Sebastopsis* Sauvage, *Sebastella* Tanaka, *Hypomacrus* Evermann and Seale, *Metzelaaria* Jordan, *Parascorpaenodes* Smith, and *Paronescodes* Smith. The genus is characterized by the combination of 13 dorsal spines, no palatine teeth, a swimbladder, and spinous procurrent caudal rays.

INTRODUCTION

Scorpionfishes of the genus *Scorpaenodes* occur along the rocky and coral reef shores of tropical and warm temperate seas. The distribution of the species of the genus is circumtropical, but the majority of the two dozen or so species occur in the western Pacific and Indian oceans. The two species described here differ from other species by living at greater depths. Interestingly, one of the species was described by J. L. B. Smith (1957, p. 65) from a specimen taken from the stomach of a snapper collected in 110 fathoms; Smith tentatively referred the specimen to *Scorpaenodes varipinnis* but noted its unusual depth of capture, and morphological and color differences. The specimens described here show that Smith's specimen does differ from *S. varipinnis*, that it normally inhabits offshore waters, and is in fact a specimen of *S. muciparus* (Alcock).

The availability of comparative material has allowed redefinition of the genus *Scorpaenodes*. A more comprehensive study of the species of this genus is in progress.

Acknowledgments

The specimens described were collected by the United States International Indian Ocean Expedition and forwarded to me by the Smithsonian Oceanographic Sorting Center. Comparative material of other species was provided by the same source and from specimens collected by the George Vanderbilt Program, which are now a part of the California Academy of Sciences fish collection.

Several persons generously aided the study. Mr. W. I. Follett, Mrs. Lillian J. Dempster, and Miss Pearl Sonoda (Department of Ichthyology) and Dr. Earl S. Herald (Steinhart Aquarium), California Academy of Sciences, assisted in many ways. Mrs. Dempster offered suggestions on the manuscript. Dr. W. Ralph Taylor (United States National Museum) provided information on the holotype of *Thysanichthys crossotus*. Photographic prints were made by Dr. G Dallas Hanna and Mr. Maurice Giles. My wife, Lydia, aided with typing, editing, and proofreading.

Methods

Counts and measurements follow Eschmeyer (1965, pp. 86–88). Terminology of spines follows Smith (1957), but other names used by some other authors are included in parentheses in many cases. Abbreviations of depositories of specimens are: CAS—California Academy of Sciences, San Francisco, California; USNM—United States National Museum, Washington, D. C.

Genus **Scorpaenodes** Bleeker

Scorpaenodes Bleeker, 1857, p. 371 (type-species *Scorpaena polylepis* Bleeker, 1857, by monotypy; no description). Matsubara, 1943, pp. 274–275 (synonymy; description; Japanese species).

Sebastopsis Gill, 1862, p. 278, footnote (type-species *Scorpaena polylepis* Bleeker, 1857, by original designation).

Sebastopsis (not of Gill) Sauvage, 1873, p. 1 (type-species *Sebastes minutus* Cuvier *in* Cuvier and Valenciennes, 1829, by original designation).

Hypomacrus Evermann and Seale, 1907, pp. 101–102 (type-species *Hypomacrus albaiensis* Evermann and Seale, 1907, by original designation; monotypic). Smith, 1958, p. 178 (two new species added).

Sebastella Tanaka, 1917, p. 10 (type-species *Sebastella littoralis* Tanaka, 1917, by monotypy).

Metzelaaria Jordan, 1923, p. 209 (type-species *Scorpaena tredecimspinosus* Metzelaar, 1919, by original designation; monotypic; misspelled as "*tridecimspinosus*").

Parascorpaenodes Smith, 1957, p. 62 (type-species *Parascorpaenodes hirsustus* Smith, 1957, by original designation; monotypic).

Paronescodes Smith, 1958, p. 177 (type-species *Paronescodes asperrimus* Smith, 1958, by original designation).

Discussion of synonymy. The genus *Scorpaenodes*, as recognized above, forms a group of small, mostly shallow-water species belonging to the subfamily

Scorpaeninae. Matsubara (1943), in his treatment of the scorpaenoid fishes of Japan, established a framework, based on osteological features, of the higher classification of scorpionfishes. Matsubara included in the synonymy of *Scorpaenodes* the nominal genera *Sebastopsis* Gill, *Sebastopsis* Sauvage, and *Sebastella* Tanaka. He did not treat *Hypomacrus* and *Metzelaaria; Parascorpaenodes* and *Paronescodes* were described subsequently.

Species of the genus *Scorpaenodes* differ from other scorpionfishes of the subfamily Scorpaeninae (except *Hoplosebastes* Schmidt, 1929) in the combination of normally 13 dorsal spines and no palatine teeth. *Hoplosebastes* differs in having two rather than three anal spines; other differences are given by Matsubara (1943, p. 267, and following). *Thysanichthys* Jordan and Starks, 1904, (the other genus in the subfamily containing species with 13 dorsal spines) differs most noticeably in having palatine teeth.

The characters used to distinguish from *Scorpaenodes* some of the nominal genera listed in the synonymy have not proved to be of generic importance in other scorpaenid groups, but rather are species' differences. Some of the characters will distinguish groups of species, but only in one geographic area.

Species of the genus *Parascorpaenodes* were separated from *Scorpaenodes* by Smith (1957, p. 62) on the basis of having fewer scales (about 30 vertical scale rows rather than more than 35), the posterior part of the lateral line irregular, and the head more completely scaled. The scalation of the head is as complete in some other species which do not share the first two characters. The lateral line is complete (except where scales have been rubbed off) in specimens available to me, but the orientation of some of the posterior lateral line scales is slightly irregular. Species referred to the nominal genus *Hypomacrus* approach in scale size those of *Parascorpaenodes,* but scale size seems not to be a generic character.

Paronescodes was separated from *Scorpaenodes* by Smith (1958, p. 177) on the basis of more spines on the suborbital ridge, more scales on the body, and a more robust body; each of these conditions is found in some species referred to other nominal genera when the species are considered on a world basis.

The species of the nominal genus *Hypomacrus* differ in having some of the middle pectoral rays elongate and in lacking nasal spines. Elongate middle pectoral rays occur in some other species but not quite to the extent as present in the two or three species referable to *Hypomacrus*. The absence of nasal spines does not seem to be a generic difference, but corresponds to a general reduction of armature in these species. Unless other differences are found, the species previously referred to *Hypomacrus* should be considered only as a species group within *Scorpaenodes*.

The genus *Metzelaaria* was proposed by Jordan (1923, p. 209) for the western Atlantic species *tredecimspinosus* Metzelaar. This species has long been recognized as a *Scorpaenodes*.

Distinguishing features. Thirteen dorsal spines, none especially elongate; procurrent rays of the caudal fin unsegmented and spinous; no palatine teeth; gas bladder present.

Description. Dorsal rays normally XIII, 8–9 (XII–XIV, 8–10), last soft ray double. Anal rays normally III, 5 (4–6), last soft ray double. Pectoral rays 15–20, some rays branched except in juveniles. Procurrent caudal rays unsegmented and spinous. Teeth on vomer; none on palatines. Scales on body ctenoid, sometimes cycloid ventrally; head usually scaled. Vertebrae normally 24. Occipital pit absent. Third suborbital bone absent; fourth suborbital bone present, but isolated, in species examined; fifth suborbital bone attached to sphenotic. Second suborbital bone uniform or gradually becoming wider posteriorly, firmly and broadly attached to preopercular margin. First three interneurals fitting between the second and third neural spines. Preorbital bone with three lobes (Matsubara's terminology), the second and third lobes (lying over the maxillary) usually rounded but sometimes as broad spinous points. Suborbital ridge with spinous points (sometimes only one at end); some species with additional suborbital spines below the main ridge. Preopercular bone with supplemental spine usually present; first, second, and third preopercular spines present, second sometimes reduced or absent; fourth and fifth preopercular spines present or absent. Two ridges usually present between orbits and sometimes ending in spines (coronal spines of Smith, 1957, but not of Matsubara, 1943; interorbital spines of Ginsburg, 1953). Postfrontal spines often present. Additional spines below parietal spines sometimes present. Other spines include nasal (absent in species previously referred to *Hypomacrus*), preocular, supraocular, postocular, tympanic (frontal spines of Ginsburg), parietal, nuchal (posterior parietal spines of Ginsburg), sphenotic (usually as a group of points), pterotic, upper and lower posttemporal, opercular, supracleithral, and cleithral; occasionally additional spinous points present on head. Small slit behind fourth gill arch small or absent. Gas bladder present.

Scorpaenodes muciparus (Alcock)

(Figure 1a, b; table 1.)

Sebastes muciparus Alcock, 1889, pp. 298–299, fig. 3 on pl. 22 (original description; type locality Bay of Bengal, 26 miles N. by E. of Gopalpur, in 45 fathoms). Alcock, 1898, pl. 18, fig. 5 (good illustration). ?Weber, 1913, p. 491 (brief description; one from *Siboga* station 306, Solor Straits, 8°27′ S., 122°54′ W., in 247 meters).

?*Scorpaenodes muciparus*, de Beaufort *in* Weber and de Beaufort, 1962, pp. 34–35 (redescription of *Siboga* specimen described by Weber).

Scorpaenodes varipinnis Smith, 1957, p. 65 (in part; only the 50-mm. specimen taken from the stomach of a specimen of *Pristipomoides microlepis* collected in 110 fathoms off Memba and tentatively referred to *S. varipinnis;* differences in color pattern and habitat between this specimen and *S. varipinnis* discussed).

REMARKS. The specimen collected by the *Siboga* (Weber, 1913) and redescribed by de Beaufort (Weber and de Beaufort, 1962) is very doubtfully a specimen of *S. muciparus*. The descriptions of the *Siboga* specimen lack sufficient information to allow definite identification, and I am not certain if it is even a specimen referable to *Scorpaenodes*. The specimen is larger in total length than any known specimen in the genus by about 50 millimeters. Branched pectoral rays are given as 4 by de Beaufort, but the specimen should have 7 or 8 branched rays if it is *S. muciparus*. Measurements are difficult to compare because of the great difference in size between the *Siboga* specimen and the other known specimens. Neither Weber nor de Beaufort mention if the procurrent caudal rays are spinous in the *Siboga* specimen.

MATERIAL EXAMINED. All specimens are from *Anton Bruun* cruise 4B: CAS no. 24264, (1, 71.2 mm.), station 279B, West Pakistan, 24°13′ N., 65°52′ E., in 93 fathoms, 9 December 1963; CAS no. 24265 (2, 45.8–48.9 mm.) station 221A, off western India, 22°32′ N., 68°07′ E., in 31.5 fathoms, 18 November 1963; CAS no. 24266 (1, 87.4 mm.) station 264A, Gulf of Oman, 25°02′ N., 56°52′ E., in 159 fathoms, 2 December 1963; USNM no. 204030 (1, 72.4 mm.) station 202A, off western India, 17°25′ N., 71°39′ E., in 52.5 fathoms, 13 November 1963.

DESCRIPTION. See also generic description. Measurements and counts summarized in table 1; body shape and color pattern in figure 1a, 1b.

Dorsal fin XIII, 9 (one specimen with XII, 10), last soft ray double. Anal fin III, 5, last soft ray double. Pectoral rays usually 19 (18–20), rays two or three through nine or ten branched in larger specimens; pectoral fin reaching to over anal soft rays. Spines on head well developed. Preorbital bone with second and third lobes each as a broad spinous point extending over the maxillary (third lobe with additional small points in larger specimens); suborbital ridge with one row of spinous points, one or more points on preorbital bone and three or more points on the suborbital bones. Interorbital ridges poorly developed, not ending in spines. Small spines (the postfrontal spines of Smith) near midline between tympanic spines usually absent (one spine in this area in two specimens). First preopercular spine long, second small and closer to first than to third, fourth broad, fifth absent; supplemental preopercular spine present. Upper posttemporal spine small or absent. Supracleithral spine double, upper part about one-half length of lower. Preocular, supraocular, and postocular spines well developed (supraocular spine double on left side of largest specimen). Small spine below parietal spine usually absent. Nasal spines present. Other spines as for the genus. Fourth suborbital bone isolated, bearing a few small spines (Ginsburg's postorbital spines). Tentacles and other fleshy skin appendages few. Supraocular tentacle about one-half orbit diameter in small specimens, shorter proportionally in larger specimens. A few tabs on upper part of eye, one

a

b

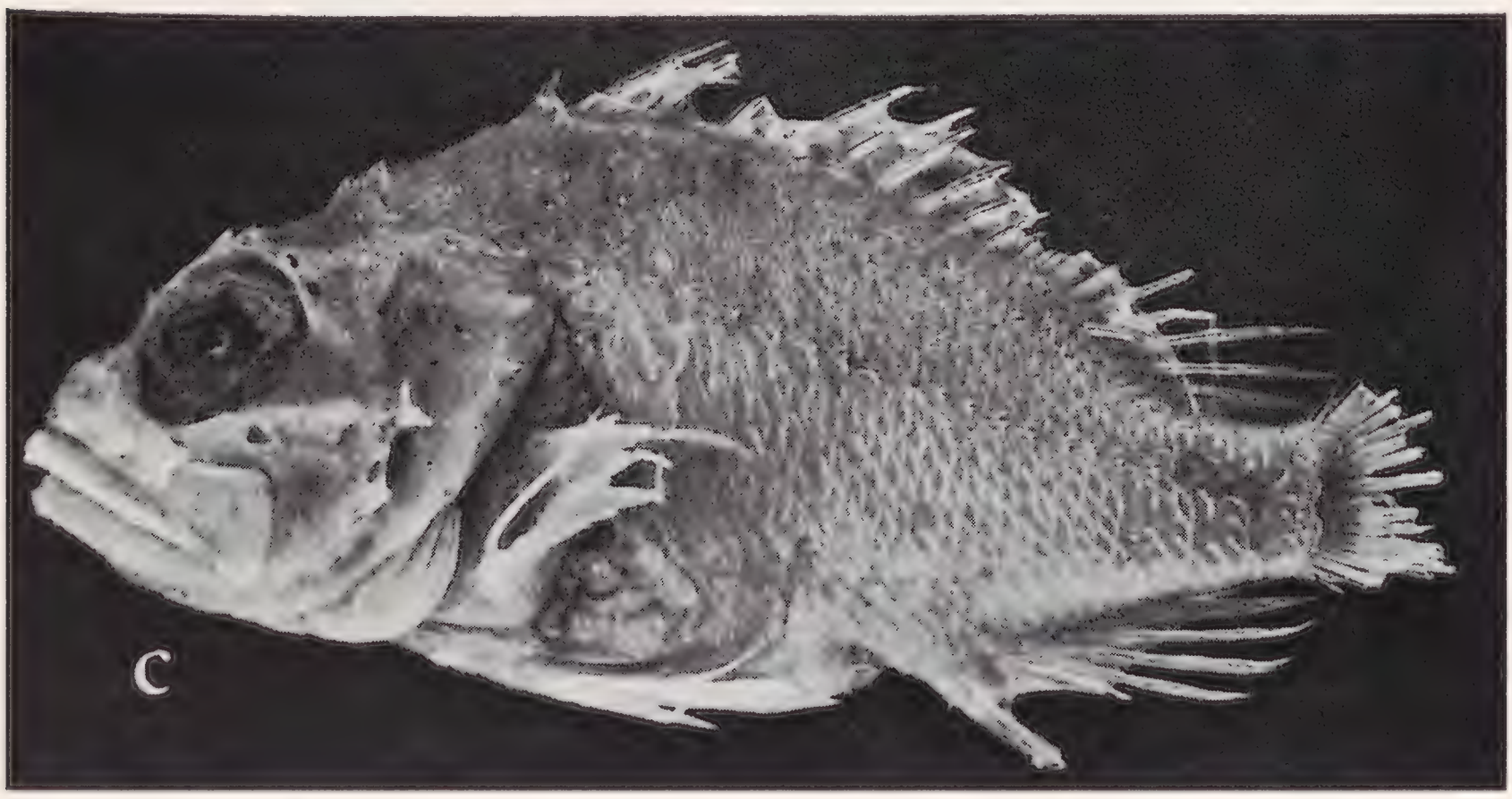
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TABLE 1. *Counts and measurements of specimens of* Scorpaenodes muciparus *and* S. tribulosus.

(Measurements are in millimeters; numbers in parentheses are percentages of standard length.)

	Scorpaenodes muciparus					*Scorpaenodes tribulosus*	
						Holotype	Paratype
Standard length	71.2	87.4	72.4	48.9	45.8	51.4	37.4
Dorsal fin rays	XII,10	XIII,9	XIII,9	XIII,9	XIII,9	XIII,8	XIII,8
Anal fin rays	III,5	III,5	III,5	III,5	III,5	III,5	III,5
Pectoral fin rays	19,20	19,18	19,19	19,19	19,19	19,19	19,19
Vertebrae	24	24	24	24	24	24	—
Gill rakers: left	6+13	6+14	6+12	6+12	6+12	5+9	5+10
right	6+11	6+13	6+13	6+12	6+12	5+8	5+10
Head length	34.8(49)	41.8(48)	37.2(51)	23.6(48)	21.5(47)	23.5(45)	17.1(45)
Snout length	8.1(11)	9.4(11)	8.0(11)	5.7(12)	4.9(11)	5.8(11)	4.3(12)
Orbit diameter	9.6(13)	11.3(13)	9.5(13)	6.8(14)	5.9(13)	7.5(15)	4.9(13)
Interorbital width	4.8(07)	5.1(06)	4.6(06)	2.9(06)	2.3(05)	3.4(07)	2.7(07)
Upper jaw length	16.7(23)	20.5(23)	16.6(23)	11.5(24)	10.2(22)	12.5(24)	8.9(24)
Predorsal-fin length	30.6(43)	36.8(42)	31.3(43)	21.6(44)	19.4(42)	23.1(45)	16.2(43)
Body depth	28.4(40)	32.3(37)	27.8(38)	20.0(41)	17.9(39)	23.2(45)	15.6(42)
Pectoral fin length	24.9(35)	32.4(37)	26.1(36)	17.6(36)	17.0(35)	—	12.6(34)
Pelvic fin length	18.1(24)	22.1(25)	18.5(26)	13.4(27)	12.5(27)	12.5(24)	10.3(28)
Caudal fin length	22.2(31)	27.8(32)	22.6(31)	15.1(31)	14.4(31)	—	11.1(30)

larger than the others. Dorsal and anal fin spines relatively long; length third dorsal spine 13–16 percent S.L., penultimate spine 5–8 percent, last spine 11–13 percent. Second anal spine longer than third, both ending at about the same point or second extending beyond third when depressed. Scales on flanks ctenoid; vertical scale rows about 50; lateral line scales about 23 plus 2 on caudal fin (many scales rubbed off in available specimens). Bases of fins with a few scales. Scales on chest and pectoral base cycloid. Dorsal parts of head scaled; underside of head unscaled or with cycloid scales. Gill rakers including rudiments 18–20; upper arch with 6 short spiny rakers; lower arch with 9–10 rakers on ceratohyal and 2–5 flat rudiments on hypohyal. Small slit present behind fourth gill arch. Color pattern as in figure 1a, 1b. The dark pigment in smaller specimens most intense on pectoral fin and as a spot on the spinous dorsal fin.

←

FIGURE 1a. *Scorpaenodes muciparus*, CAS no. 24266, 71.2 mm. S.L., off West Pakistan, 24°13′ N., 65°52′ E., in 93 fathoms; 1b. *Scorpaenodes muciparus*, CAS no. 24265, 48.9 mm. S.L., off western India, 22°32′ N., 68°07′ E., in 31.5 fathoms; 1c. *Scorpaenodes tribulosus*, CAS no. 24267, holotype, 51.4 mm. S.L., off Kenya, 02°42′ S., 40°53′ E., in 77 fathoms.

Comparisons. Most species of the genus are reef inhabitants occurring in very shallow water, but the present species and *Scorpaenodes tribulosus* appear to be exceptions. *Scorpaenodes muciparus* has been taken in depths from 31–159 fathoms and *S. tribulosus* from 77 and 40 to 96 fathoms. *Scorpaenodes tredecim-spinosus* from the western Atlantic has been collected from as deep as 50 fathoms, but it usually occurs in depths from 10–20 fathoms. Other species of the genus are shore forms which rarely descend below about 10 fathoms.

Groups of species of *Scorpaenodes* differ from *S. muciparus* in lacking a spot on the spinous dorsal fin, having shorter dorsal spines, having extra spines below the suborbital ridge, having spines on the interorbital ridges, lacking nasal spines, having fewer scales, and having eight rather than nine soft dorsal rays. Most of the shallow-living species are characteristically brightly colored.

The specimen tentatively referred to *S. varipinnis* by Smith (1957, p. 65) is a specimen of *S. muciparus*. *Scorpaenodes muciparus* differs from *S. varipinnis* in having normally nine rather than eight soft dorsal rays, more spines on the suborbital ridge (usually one on preorbital and three or more on suborbitals versus one plus two), and smaller scales. The color pattern and depth of capture of Smith's specimen also agree with *S. muciparus*. *Scorpaenodes muciparus* is compared with *S. tribulosus* under the account of *S. tribulosus*.

Distribution. *Scorpaenodes muciparus* is known from the type collected in the Bay of Bengal and from the five specimens described here which were collected in the Gulf of Oman and in the Arabian Sea off western India and West Pakistan. The specimen reported on by Smith (1957, p. 65) was taken off Memba, Mozambique. Depths of capture range from 31 to 159 fathoms.

Scorpaenodes tribulosus Eschmeyer, new species.

(Figure 1c; table 1.)

Holotype. CAS no. 24267, a specimen 51.4 mm. in standard length, *Anton Bruun* cruise 8, station 420A, off Kenya, 02°42′S., 40°53′E., in 77 fathoms, field no. LK 64-101, 6 November 1964.

Paratype. USNM no. 204031 (1, 37.4 mm.) *Anton Bruun* cruise 9, station 463, off Somali Republic, 11°24′N., 51°35′E., in 40–96 fathoms, 17 December 1964.

Description. See also generic description. Measurements and counts summarized in table 1; body shape and color pattern in figure 1c.

Dorsal fin XIII, 8, last soft ray double. Anal fin III, 5, last soft ray double. Pectoral rays 19, some rays branched (rays broken distally in holotype; paratype with rays 3–9 or 10 branched, second rays broken; probably rays 2 through 9 or 10 usually branched in specimens of this size); pectoral fin reaching to level of first anal spine. Spines on head fragile. Preorbital bone with second lobe as a broad rounded shelf and third lobe broad with two small points in

holotype and one point in paratype; several small spinous points on preorbital bone in front of eye. Suborbital ridge with 6–8 poorly defined spinous points in holotype and 4 in paratype. (Much variability is expected in suborbital spination; the usual condition is probably one spine on the preorbital in line with three on the suborbitals; the condition in the holotype represents a splitting of some of these.) A strong ridge on anterior margin of pore between first and second suborbital bones. Interorbital ridges poorly developed, ending in small upright spines (coronal spines of Smith) in holotype and absent in paratype (variable in other species also). No postfrontal spines near midline between the tympanic spines (usually variable in other species). Preopercular spines fairly small; supplemental and five preopercular spines present; second preopercular spine slightly smaller than first or third and closer to first. Upper posttemporal spine small or absent. Supracleithral spine double, upper part about one-half length of lower part. Spine below parietal spine absent. Nasal spines present. Fourth suborbital bone isolated, with low spinous points (postorbital spines of Ginsburg). Other spines as for the genus. Skin appendages poorly developed. Supraocular tentacle less than one-half orbit diameter. Dorsal and anal fin spines relatively long; length third dorsal spine 17 percent S.L. (paratype), penultimate 4 percent (paratype), last spine broken in both specimens. Second anal spine about equal to or slightly longer than third, second extending beyond third when depressed. Scales on body strongly ctenoid. Vertical scale rows about 45 (some scales rubbed off in available specimens). Bases of fins with ctenoid scales. All of head, including nape, interorbital area, edge of eye, jaws, and underside of head with small ctenoid scales. Scales on chest and pectoral-fin base mostly ctenoid. Gill rakers including rudiments 14–15; upper arch with 5 rakers; lower arch with 9 rakers on ceratohyal and 0–1 rudiment on hypohyal. Small slit present behind fourth gill arch. Body shape and color pattern as in figure 1c. Holotype mostly pallid, with a few dark specks on membranes between posterior dorsal spines. Paratype pallid except for dark spot between dorsal spines 8–11. A minute dusky tentacle at left nuchal spine in paratype. Head pores better developed than in other species of the genus, especially those pores associated with the preorbital bone, between the preorbital and first suborbital bone, and between first and second suborbital bones.

COMPARISONS. This species is characterized by the presence of extremely rough scales caused by numerous long ctenii, especially on the scales about the head. *Scorpaenodes parvipinnis* (Garrett, 1863) (= *Paronescodes asperrimus* Smith, 1958) also has strongly ctenoid scales, but the ctenii of scales in *S. tribulosus* are longer, and the degree of scalation on the underside of the head and on the maxillaries is stronger in *S. tribulosus*. The head pores appear to be proportionally larger in *S. tribulosus* than in other species of *Scorpaenodes* (larger pores are usually found in the deeper-living species of each genus). *Scorpaenodes tribulosus* agrees with *S. muciparus* in living in deeper water than other species

of the genus. *Scorpaenodes tribulosus* is most easily distinguished from *S. muciparus* in usually having 8 rather than 9 soft dorsal rays, and in having the underside of the head covered with ctenoid scales rather than being naked or covered with cycloid scales.

Distribution. The species is known from the two type specimens from off northwest Africa at Kenya and the Somali Republic in 77 and between 40–96 fathoms respectively.

Name. The species is named "*tribulosus*," the Latin word for thorny, alluding to the strongly ctenoid scales.

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A New Genus of Silicoflagellata from an Eocene South Atlantic Deep-Sea Core (Protozoa: Mastigophora)

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ABSTRACT: A study of diatoms of Eocene age from south Atlantic deep-sea cores by Messrs. G D. Hanna, I. N. Hendey, and A. L. Brigger, resulted in the discovery of many silicoflagellates among which was *Hannaites quadria*, new genus and new species. The holotype, and all paratypes used in this study are deposited in the California Academy of Sciences Department of Geology Type Collection.

INTRODUCTION

Mounted specimens of silicoflagellates belonging to this new genus were given to me for description by Dr. G Dallas Hanna. They were found by Dr. Hanna and Dr. A. L. Brigger in a core collected by the Lamont Geological Observatory, Columbia University. The specimens were found during a California Academy of Sciences study of the diatom flora of this core.

The locality data are as follows: R/V *Vema* Cruise 17; core number, 107; water depth, 1525 meters; distance from top of core, 245 cm.; date of coring, 13 May 1961; latitude, 51°08′S.; longitude, 54°22′W.; age, Eocene; California Academy of Sciences locality number 39573 (9). A second Eocene sample, identical in all locality data details except distance from the top of the core, also contains this new genus. Its distance from the top of the core is 120 cm.

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OCT 30 1969

The photographs were made by Dr. Hanna. Because they were taken at high magnification, there is a depth of field problem. The raised apical bridge is not in the same plane as the basal ring. Hence the basal ring is in focus and the apical ring is out of focus.

Because silicoflagellates are not commonly seen, even by most micropaleontologists, a short statement about these rare microorganisms is included here.

Silicoflagellates are marine planktonic protistids with a flagellum and a skeleton of hollow siliceous rods. In the past they have been considered to be animals, plants, and microorganisms that have characters of both. In this paper they are classified under the rules of the International Commission of Zoological Nomenclature. A few species are living today and some have been found in rocks as old as late Cretaceous. (There are reports of older silicoflagellates, but they have not been adequately confirmed.) Studies by Mandra and Hanna indicate that these microfossils can be useful in stratigraphy and paleoecology.

All major papers on silicoflagellates were examined in order to make sure that the specimens described here are new.

Acknowledgment

I wish to thank Dr. G Dallas Hanna for the priviledge of studying and reporting this new genus, for the use of the Academy's mounted specimens, for the excellent photographs, and for helpful comments and discussions. This study was supported by the Antarctic Programs of the National Science Foundation. *Vema* Cruise 17 was organized by Dr. M. Ewing, Director of Lamont Geological Observatory, and funded by the Office of Naval Research.

SYSTEMATICS

Order SILICOFLAGELLATA Borgert

Family Dictyochidae Deflandre[1]

Description. Skeleton normally a basal ring and an apical bridge.

Range. Late Cretaceous to Recent. Cosmopolitan.

Genus **Hannaites** Mandra, new genus

Type species. *Hannaites quadria* Mandra, new species.

Etymology. Generic dedication is made to honor Dr. G Dallas Hanna of the California Academy of Sciences.

Description. Basal ring consists of four side tubes nearly equal in length; each side tube may be straight, gently arcuate, or form an obtuse angle; the tubes are covered with small evenly spaced bosses (knobs or nodes); the diameter of these tubes is relatively small when compared to the length of each side tube (ratio varies from 1:15 to 1:25); and the basal ring may or may not have a few supporting spines.

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1 Dictyochaceae Lemmermann, 1901, p. 255

At each of the four corners of the basal ring there is a large, well rounded, spherical-like protuberance, the diameter of which is approximately three to four times the diameter of the basal ring tubes. On each of the four protuberances there are small, evenly spaced bosses (smaller protuberances). In the center of each of the four, large, corner structures there appears to be an inner sphere which seems to connect to the canals inside the basal ring tubes.

The apical bridge is a simple elevated tube connected at each end to two supporting tubes. Each of the latter four tubes are in turn attached to the central region of each of the four basal ring tubes. The height of the top of the apical bridge above the plane of basal ring is one-fifth to one-eighth the length of a basal ring tube.

AGE, DISTRIBUTION, AND TYPE LOCALITY. Eocene. The genus has been found only in the South Atlantic deep-sea core described earlier in this paper. The Eocene age is based upon that of the associated diatom flora and confirmed by the remaining silicoflagellate fauna, both of which clearly indicate Eocene age.

REMARKS. This new genus bears a resemblance to *Dictyocha* in its apical bridge structure. It differs from *Dictyocha* in the possession of large, prominent, spherical-like protuberances at each of the four corners of the basal ring.

Corbisema geometrica Hanna, *Dictyocha triacantha inermis* Lemmermann, *D. archangelskiana* (Schulz), *D. bimucronata* (Deflandre), and *Phyllodictyocha schulzi* Deflandre, like the new species, have no radiating basal spines. They differ by having a three-rayed apical bridge. The new genus has a five-rayed apical bridge. Also, the other genera do not have the prominent, corner, spherical-like protuberances.

Dictyocha quadralta Hanna, 1928, is remarkably similar to the one species of this new genus. The two species differ in that *Hannaites quadria*, new species, has pronounced spherical-like protuberances, whereas *Dictyocha quadralta* has only short spines. Deflandre (1950) transferred *Dictyocha quadralta* to the genus *Corbisema*.

Hannaites quadria Mandra, new species.

(Figures 1, 2, 3, 4, 5, 6, 7.)

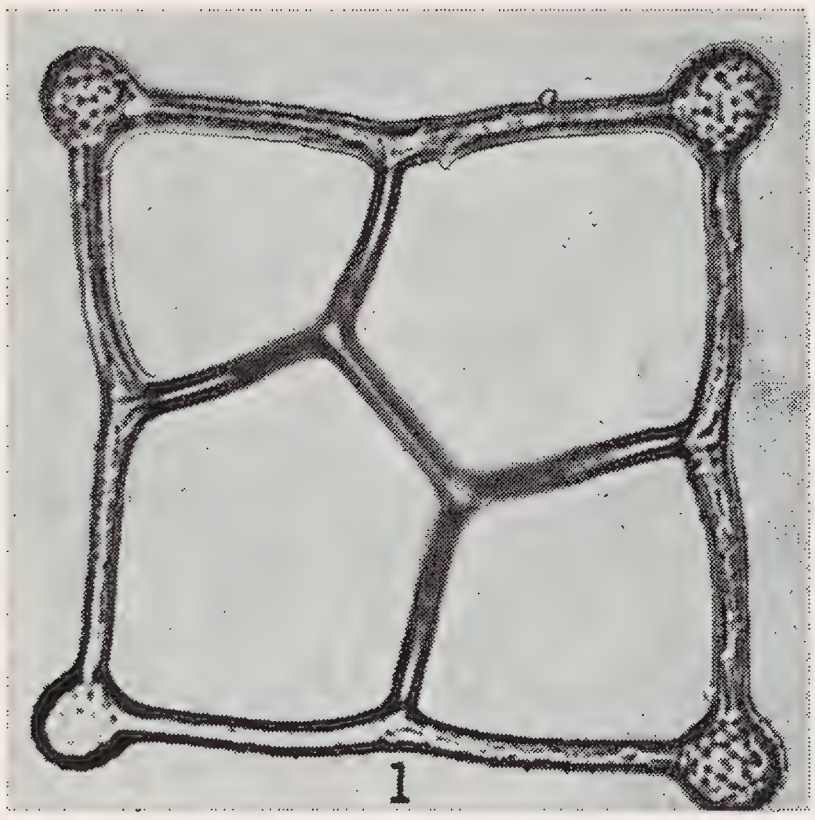
DESCRIPTION. Same as for the genus.

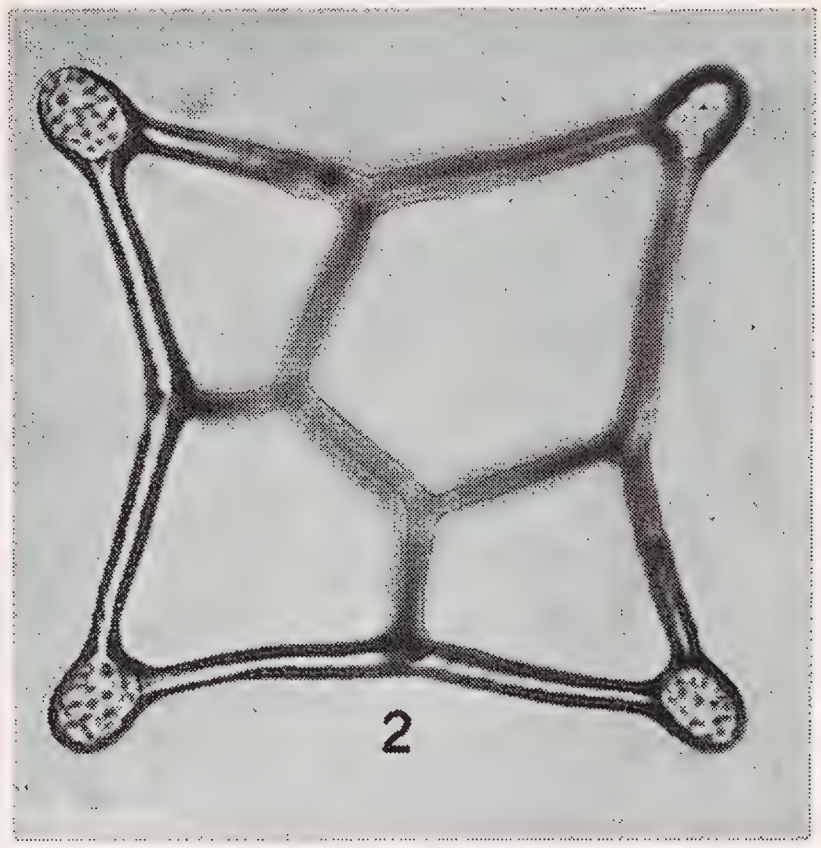
HOLOTYPE, no. 3954, California Academy of Sciences, Department of Geology, Type Collection. Locality no. 39573 (9) (CAS). (See Introduction.)

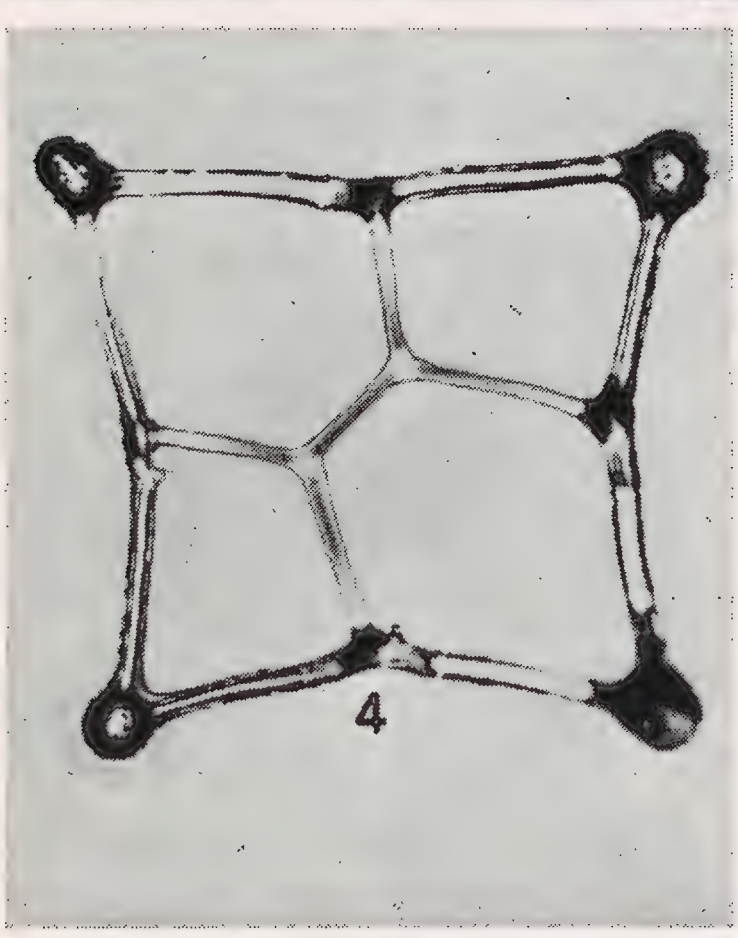
PARATYPES, nos. 3955, 3956, 3957, 3958, California Academy of Sciences, Department of Geology, Type Collection. Locality 35573 (9) (CAS).

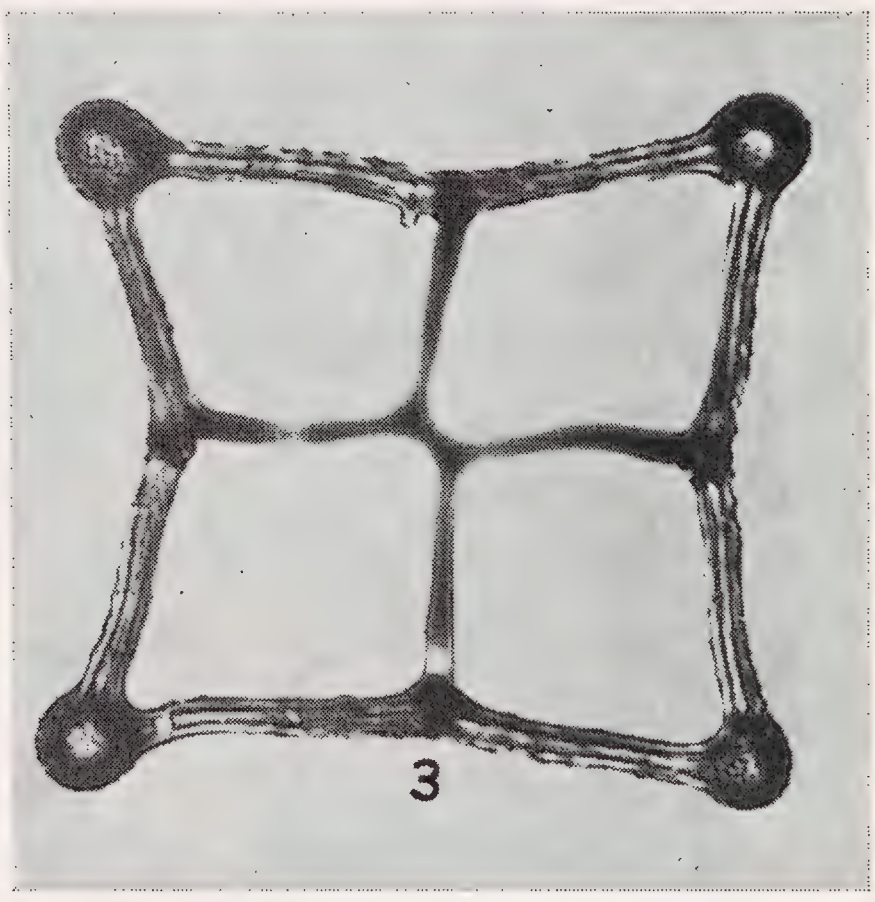
AGE, DISTRIBUTION, AND TYPE LOCALITY. Same as for the genus.

REMARKS. The holotype was selected from four specimens on one slide because its outline of four gently-concave sides seems more typical of the species









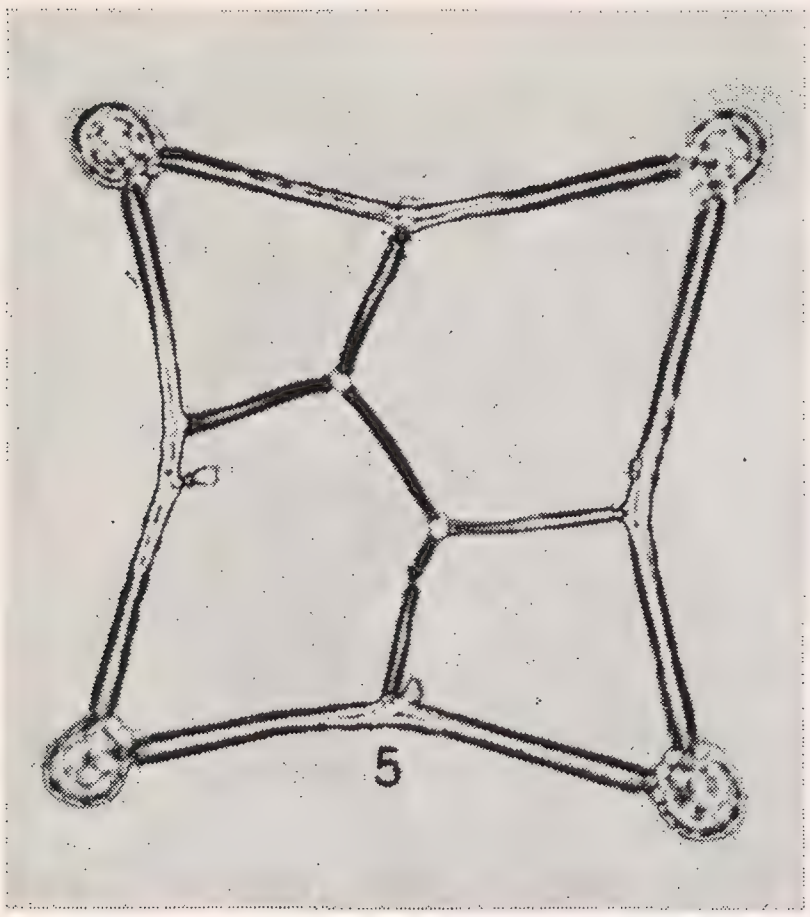
Figures 1–4. *Hannaites quadria* Mandra, new species. Figure 1. Paratype no. 3955 (CAS). Maximum dimension, 87 microns; central apical tube length, 15 microns.

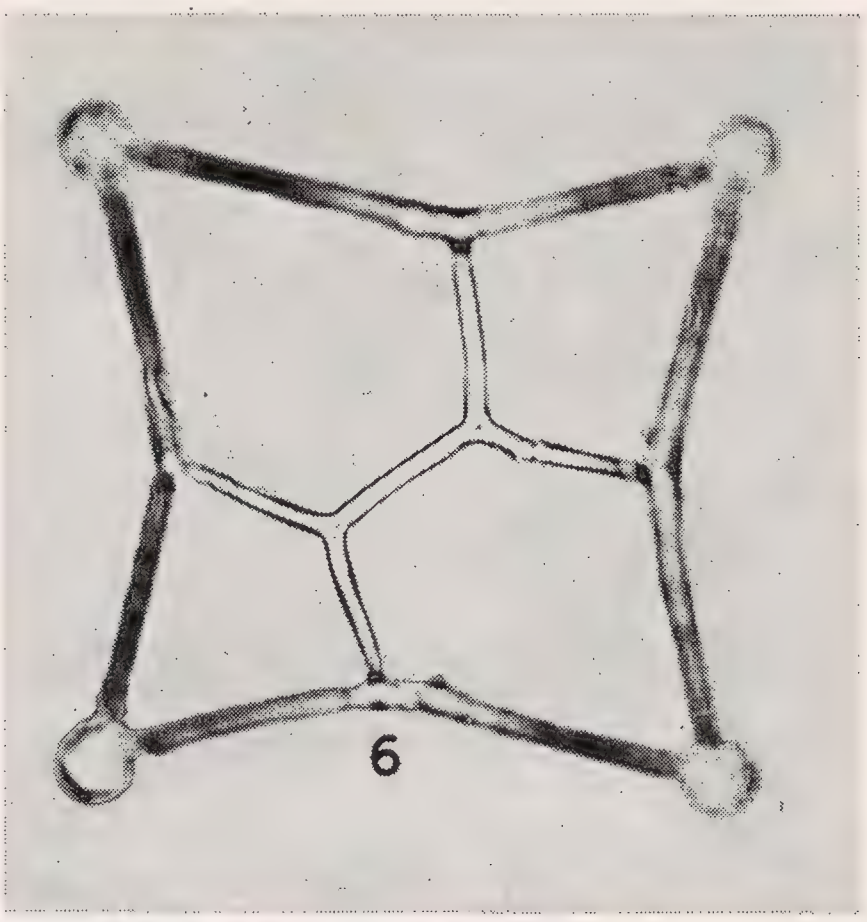
Figure 2. Holotype no. 3954 (CAS). Maximum dimension, 82 microns; central apical tube length, 14 microns.

Figure 3. Paratype no. 3956 (CAS). Maximum dimension, 80 microns; central apical tube length, 4 microns.

Figure 4. Paratype no. 3957 (CAS). Maximum dimension, 83 microns; central apical tube length, 15 microns.

than the straight-sided form. Two paratypes have an outline similar to the holotype, but in one case the apical bridge is atypically short, and in the other case one supporting bar of the apical bridge is broken.





FIGURES 5–7. *Hannaites quadria* Mandra, new species. FIGURE 5. Basal ring in focus. Paratype no. 3958 (CAS). Maximum dimension 74 microns; central apical tube length, 12 microns.

FIGURE 6. Apical ring in focus. Paratype no. 3958 (CAS). Maximum dimension, 74 microns; central apical tube length, 12 microns.

FIGURE 7. External details of small boss of a corner protuberance of Paratype no. 3958 (CAS). Maximum external diameter of spherical-like structure, 6 microns.

Paratype (no. 3956, fig. 3) displays the inner canals more clearly than the holotype. Paratypes (nos. 3956, 3958, figs. 3, 6) have basal ring structures which appear to be undeveloped spines.

Measurements in microns of types are as follows:

Specimen	Long axis	Short axis	Central apical tube length	Basal ring tube diameter	Diameter of corner protuberances
Paratype no. 3958 (Figures 5, 6, 7)	74	71	12	2	6
Holotype no. 3954 (Figure 2)	82	79	14	2	7
Paratype no. 3956 (Figure 3)	80	81	4	3	8
Paratype no. 3957 (Figure 4)	83	82	15	2	9
Paratype no. 3955 (Figure 1)	87	82	15	2	9
Mean of five types	81	79	12	2	8
Median of five types	82	81	14	2	8

Subsequent to this description, Dr. Hanna found another specimen of this new genus. Its dimensions are consistent with the above.

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No. 78, 9 pages, 17 figures. October 22, 1969

Three New Species Of Burrowing Bryozoans (Ectoprocta) From The Hawaiian Islands

By

John D. Soule and Dorothy F. Soule

Allan Hancock Foundation, University of Southern California, University Park, Los Angeles, California 90007

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No. 78, 9 pages, 17 figures. October 22, 1969

Three New Species Of Burrowing Bryozoans (Ectoprocta) From The Hawaiian Islands

By

John D. Soule[1] and Dorothy F. Soule[2]

Abstract: Recent collecting in the waters off the Hawaiian Islands under the auspices of a National Science Foundation Grant GB 5208, has produced the first records of penetrating bryozoans in the mid-Pacific. Two are known species: *Penetrantia parva*, described from New Zealand (Silén, 1946), and *Immergentia zelandica minuta* Soule, 1950, described from Zamboanga, Philippine Islands. Three new species are included in this report: *Terebripora varians*, *Penetrantia operculata*, and *Immergentia angulata*.

Introduction

D'Orbigny first described the tracings on mollusk shells made by burrowing bryozoans, and erected the genus *Terebripora* in 1847, but it was not until the work of Marcus (1938) that the anatomy of the zoids became known. Marcus (1938) reported one of d'Orbigny's species, *Terebripora ramosa*, in Brazilian waters that had first been described from Chile and Peru. Two new genera and twelve new species have since been described and the anatomy of the zoids figured (Silén, 1946, 1947; Soule, 1950a, 1950b; Soule and Soule, 1968).

Past distribution records, although sparse, suggest that the species may be widely distributed. For example, Bobin and Prenant (1954) found *Terebripora comma* Soule, 1950, described from California, in the Mediterranean. Soule

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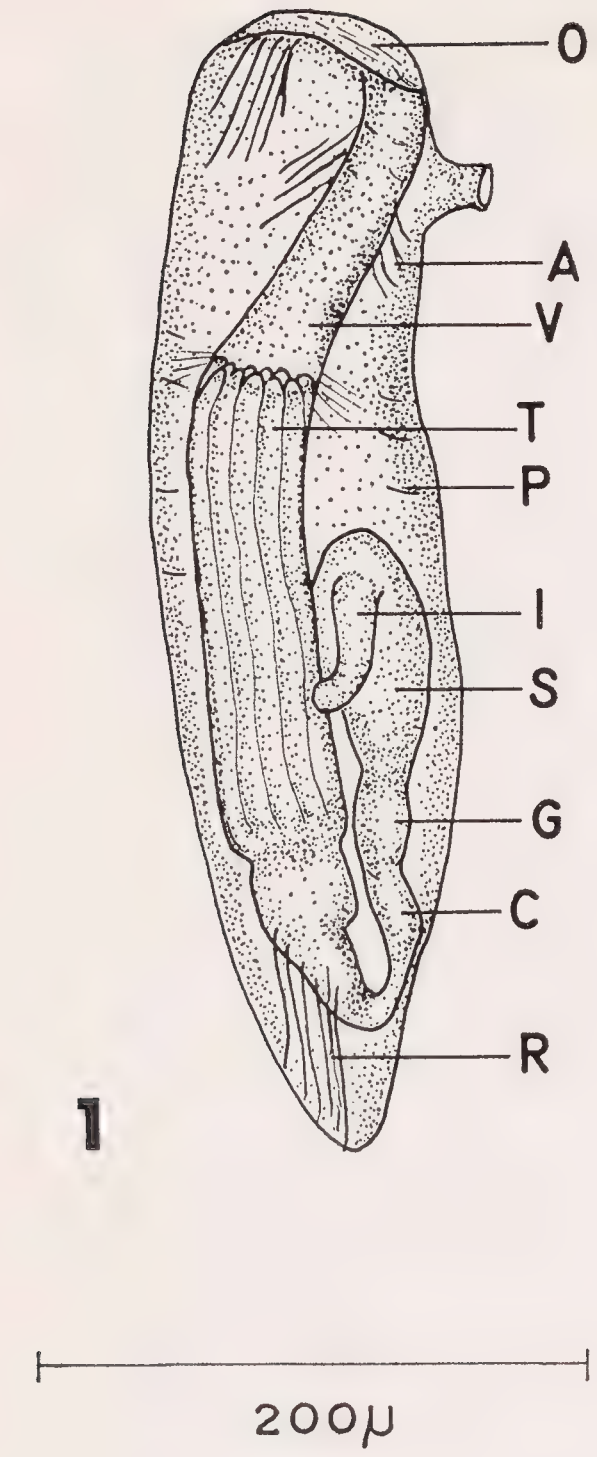

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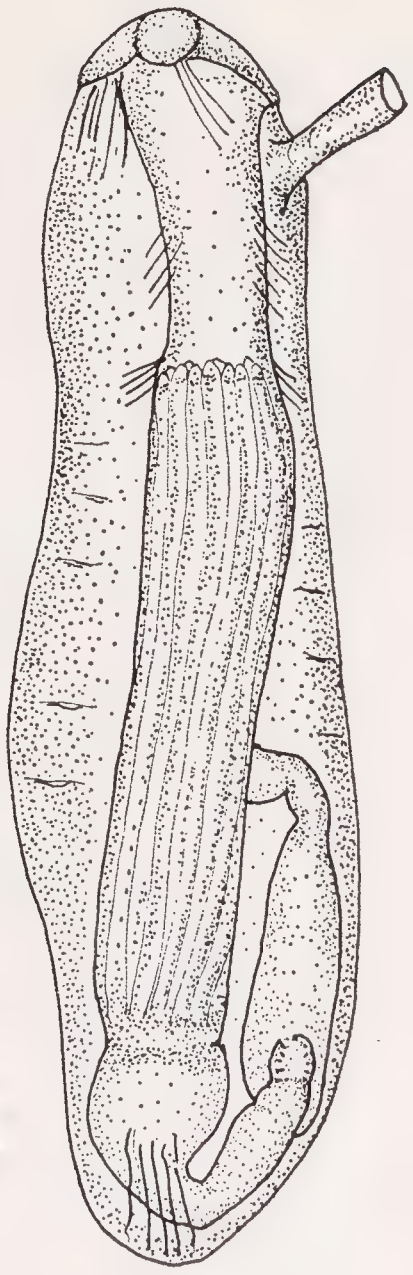

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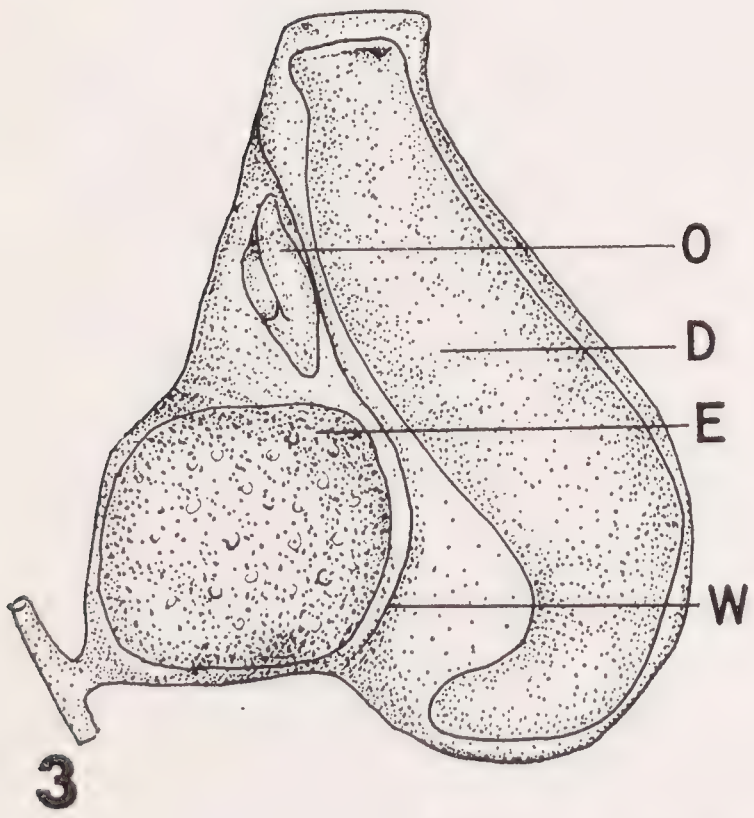

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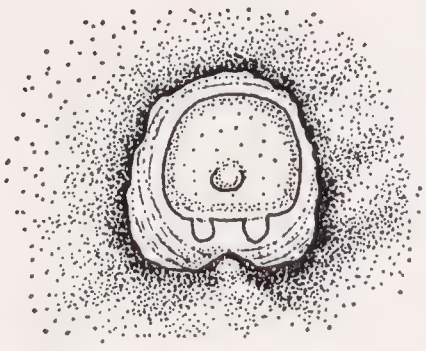

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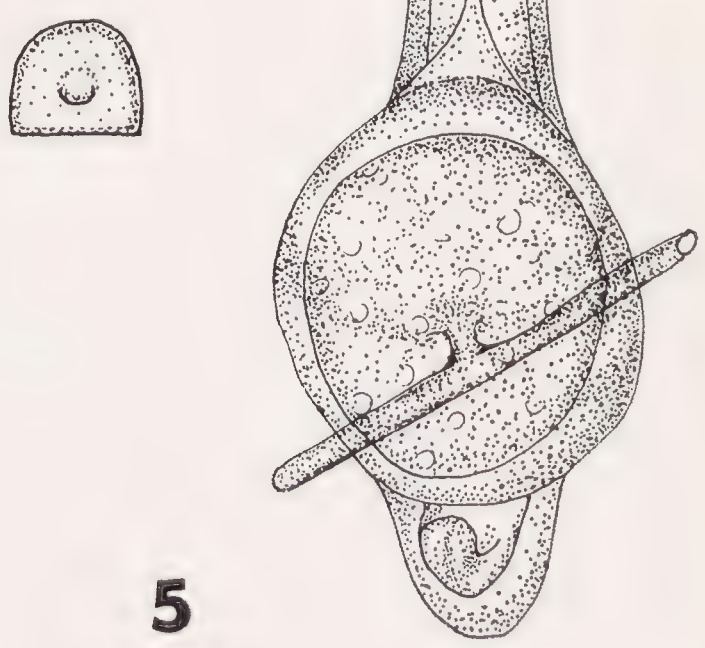

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FIGURE 1. *Penetrantia parva* Silén; autozoid.

FIGURE 2. *Penetrantia operculata*, new species; autozoid with knobbed operculum.

found *Penetrantia concharum* and *Penetrantia densa*, described originally from Sweden and South Africa respectively, in California waters (Soule, 1950). A new species, *Terebripora eltaninae* Soule and Soule, 1968, was recently described from the Antarctic, inhabiting *Cephalodiscus*.

The authors wish to express their appreciation to James McVey, Stanley Swerdloff, and Greg Stanton, of the Department of Zoology, University of Hawaii, whose efforts were responsible for the collection of the bryozoans reported in this paper. We also wish to thank Mr. James Smola for his assistance in the preparation of serial sections.

Methods and Materials

Gastropod shells showing the surface tracings of burrowing bryozoans were immediately fixed and preserved in neutral formalin when collected in the field. Transported to the laboratory, the gastropods were identified and examined wet under a dissecting microscope. Each specimen was given an identifying number and carefully broken into small fragments. The fragments were examined wet and some fragments were air-dried to preserve a record of the surface traces while the remainder were decalcified in 5 percent trichloracetic acid, then washed in several changes of tap and distilled water, and stored in 70 percent ethanol. Some of the decalcified material was then stained with azo-carmine, dehydrated, and mounted for anatomical studies. The remaining decalcified material was dehydrated, imbedded in paraffin and serial sections were cut at 3–4 microns. These were stained with hematoxylin and eosin, and examined histologically as well as for accurate tentacle count.

Systematic Accounts

Genus **Penetrantia** Silén, 1946

Penetrantia parva Silén, 1946.
(Figure 1.[3])

Penetrantia parva Silén, 1946, pp. 4–5, fig. 7.

The Hawaiian specimens agree in all respects with Silén's description. The autozoids range in length from 400 to 440 microns, and are pointed proximally.

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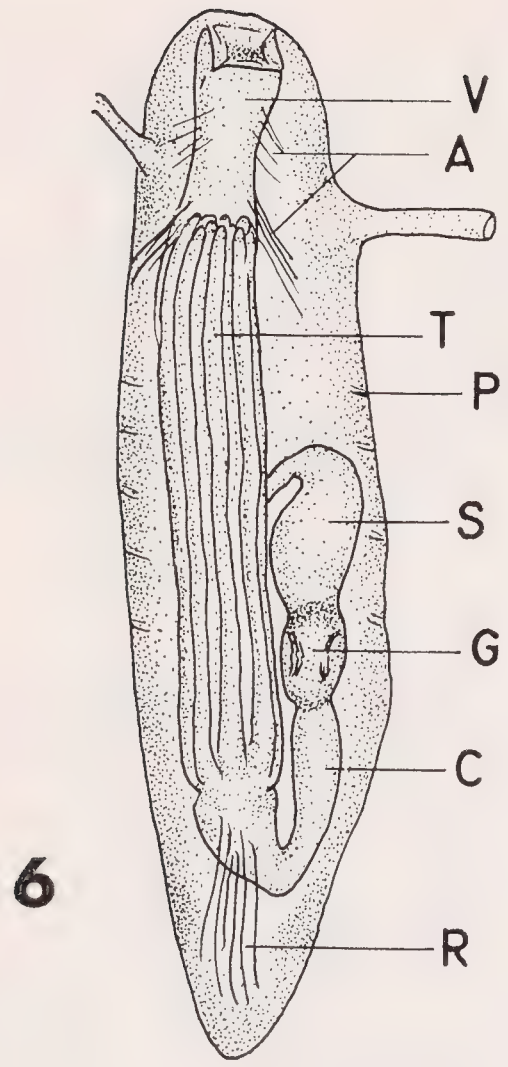
[3] A, apertural muscles; B, brown body; C, cardia; D, degenerate polypide; E, ovum or embryo; G, gizzard; I, intestine; O, operculum; P, parietal muscles; R, retractor muscles; S, stomach; T, tentacles; V, vestibule; W, wall of embryo chamber.

←

Figure 3. *P. operculata*, new species; gonozoid showing separate embryo chamber with ovum and with stolon attached. Operculum is freed from aperture and lies in embryo chamber when polypide degenerates.

Figure 4. *P. operculata*, new species; aperture in shell, with aperture of zoid beneath shell surface. Note knobbed operculum, central denticle (lyrula), and lateral denticles (cardelles).

Figure 5. *P. operculata*, new species; gonozoid showing attachment of embryo chamber.



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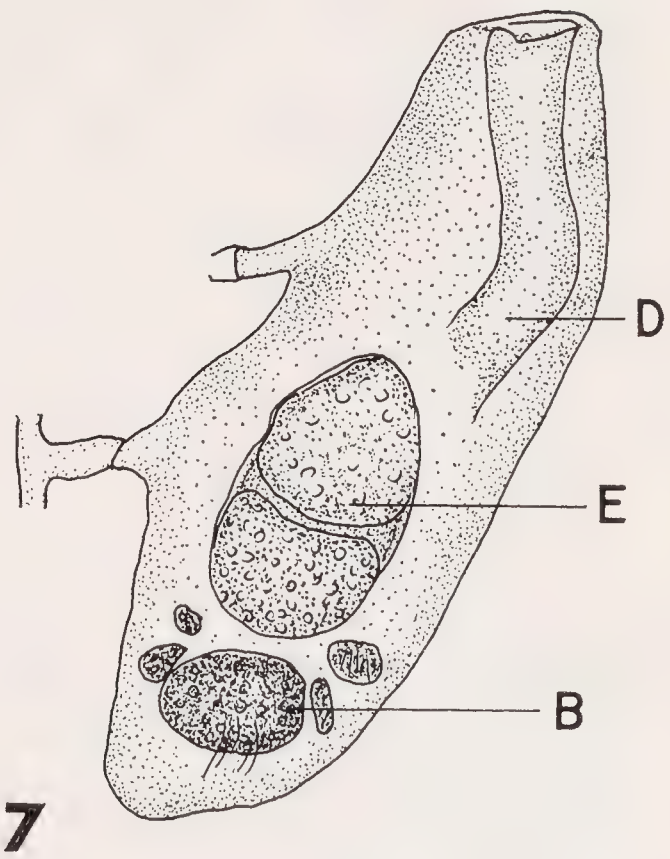

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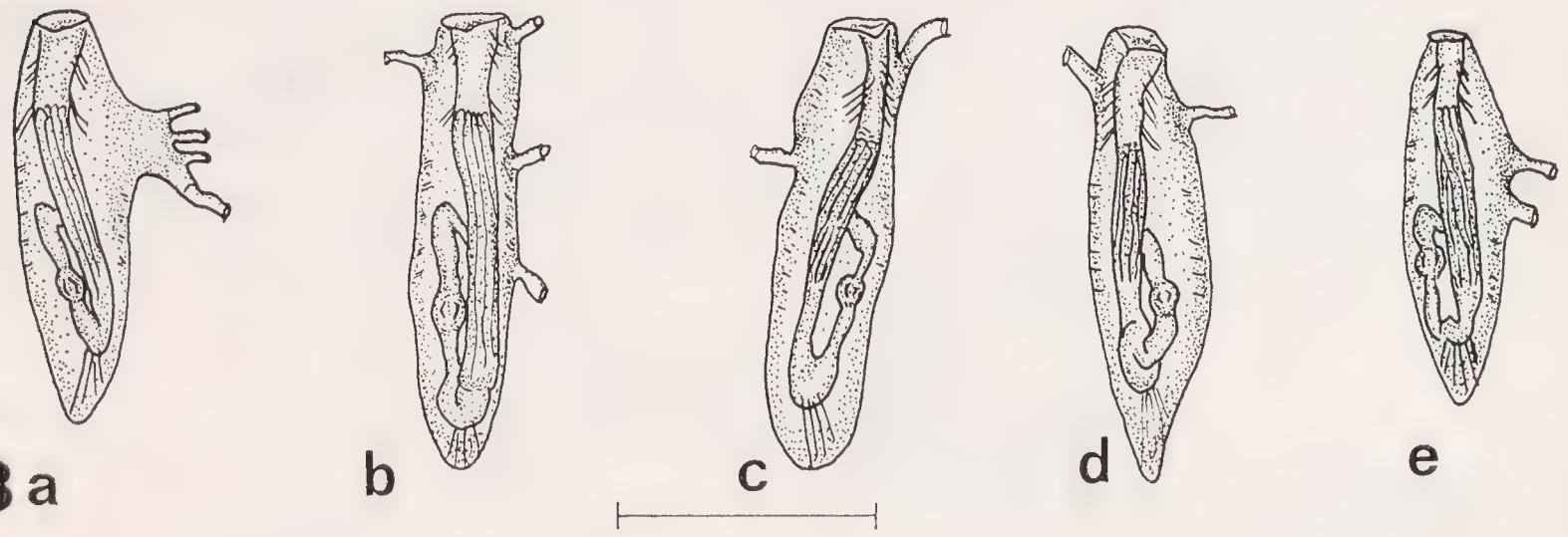

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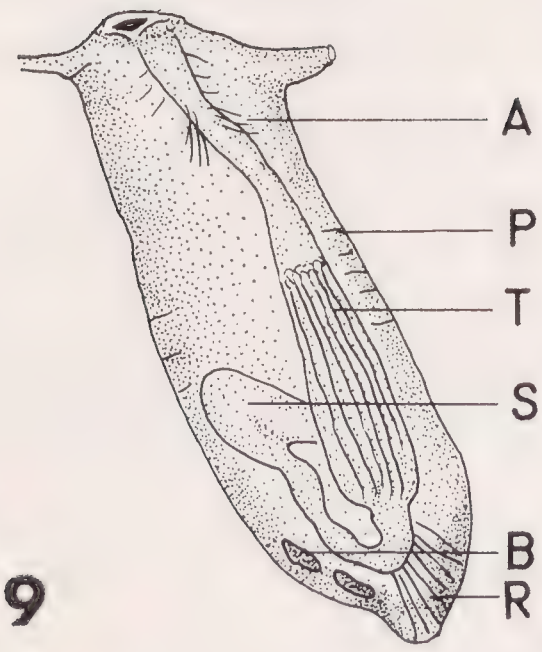

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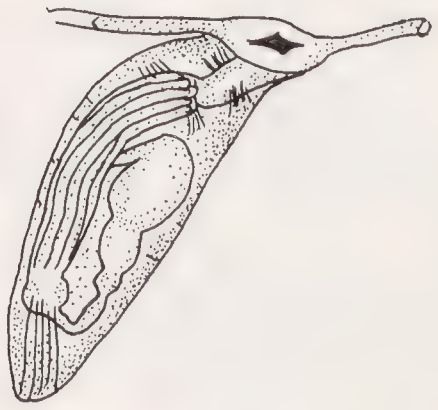

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No. 76, 11 pages, 1 table, 1 figure. October 22, 1969

A New Scorpionfish of the Genus *Scorpaenodes* and *S. muciparus* (Alcock) from the Indian Ocean, with Comments on the Limits of the Genus

By

William N. Eschmeyer

California Academy of Sciences, San Francisco, California 94118

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ABSTRACT: *Scorpaenodes muciparus* (Alcock) and a new species, *S. tribulosus*, are described from the Indian Ocean. These two species occur in deeper water than do the other members of the genus. The genus *Scorpaenodes* is redefined to include the following nominal genera: *Sebastopsis* Gill, *Sebastopsis* Sauvage, *Sebastella* Tanaka, *Hypomacrus* Evermann and Seale, *Metzelaaria* Jordan, *Parascorpaenodes* Smith, and *Paronescodes* Smith. The genus is characterized by the combination of 13 dorsal spines, no palatine teeth, a swimbladder, and spinous procurrent caudal rays.

INTRODUCTION

Scorpionfishes of the genus *Scorpaenodes* occur along the rocky and coral reef shores of tropical and warm temperate seas. The distribution of the species of the genus is circumtropical, but the majority of the two dozen or so species occur in the western Pacific and Indian oceans. The two species described here differ from other species by living at greater depths. Interestingly, one of the species was described by J. L. B. Smith (1957, p. 65) from a specimen taken from the stomach of a snapper collected in 110 fathoms; Smith tentatively referred the specimen to *Scorpaenodes varipinnis* but noted its unusual depth of capture, and morphological and color differences. The specimens described here show that Smith's specimen does differ from *S. varipinnis*, that it normally inhabits offshore waters, and is in fact a specimen of *S. muciparus* (Alcock).

The availability of comparative material has allowed redefinition of the genus *Scorpaenodes*. A more comprehensive study of the species of this genus is in progress.

Acknowledgments

The specimens described were collected by the United States International Indian Ocean Expedition and forwarded to me by the Smithsonian Oceanographic Sorting Center. Comparative material of other species was provided by the same source and from specimens collected by the George Vanderbilt Program, which are now a part of the California Academy of Sciences fish collection.

Several persons generously aided the study. Mr. W. I. Follett, Mrs. Lillian J. Dempster, and Miss Pearl Sonoda (Department of Ichthyology) and Dr. Earl S. Herald (Steinhart Aquarium), California Academy of Sciences, assisted in many ways. Mrs. Dempster offered suggestions on the manuscript. Dr. W. Ralph Taylor (United States National Museum) provided information on the holotype of *Thysanichthys crossotus*. Photographic prints were made by Dr. G Dallas Hanna and Mr. Maurice Giles. My wife, Lydia, aided with typing, editing, and proofreading.

Methods

Counts and measurements follow Eschmeyer (1965, pp. 86–88). Terminology of spines follows Smith (1957), but other names used by some other authors are included in parentheses in many cases. Abbreviations of depositories of specimens are: CAS—California Academy of Sciences, San Francisco, California; USNM—United States National Museum, Washington, D. C.

Genus **Scorpaenodes** Bleeker

Scorpaenodes Bleeker, 1857, p. 371 (type-species *Scorpaena polylepis* Bleeker, 1857, by monotypy; no description). Matsubara, 1943, pp. 274–275 (synonymy; description; Japanese species).

Sebastopsis Gill, 1862, p. 278, footnote (type-species *Scorpaena polylepis* Bleeker, 1857, by original designation).

Sebastopsis (not of Gill) Sauvage, 1873, p. 1 (type-species *Sebastes minutus* Cuvier *in* Cuvier and Valenciennes, 1829, by original designation).

Hypomacrus Evermann and Seale, 1907, pp. 101–102 (type-species *Hypomacrus albaiensis* Evermann and Seale, 1907, by original designation; monotypic). Smith, 1958, p. 178 (two new species added).

Sebastella Tanaka, 1917, p. 10 (type-species *Sebastella littoralis* Tanaka, 1917, by monotypy).

Metzelaaria Jordan, 1923, p. 209 (type-species *Scorpaena tredecimspinosus* Metzelaar, 1919, by original designation; monotypic; misspelled as "*tridecimspinosus*").

Parascorpaenodes Smith, 1957, p. 62 (type-species *Parascorpaenodes hirsustus* Smith, 1957, by original designation; monotypic).

Paronescodes Smith, 1958, p. 177 (type-species *Paronescodes asperrimus* Smith, 1958, by original designation).

Discussion of synonymy. The genus *Scorpaenodes*, as recognized above, forms a group of small, mostly shallow-water species belonging to the subfamily

Scorpaeninae. Matsubara (1943), in his treatment of the scorpaenoid fishes of Japan, established a framework, based on osteological features, of the higher classification of scorpionfishes. Matsubara included in the synonymy of *Scorpaenodes* the nominal genera *Sebastopsis* Gill, *Sebastopsis* Sauvage, and *Sebastella* Tanaka. He did not treat *Hypomacrus* and *Metzelaaria; Parascorpaenodes* and *Paronescodes* were described subsequently.

Species of the genus *Scorpaenodes* differ from other scorpionfishes of the subfamily Scorpaeninae (except *Hoplosebastes* Schmidt, 1929) in the combination of normally 13 dorsal spines and no palatine teeth. *Hoplosebastes* differs in having two rather than three anal spines; other differences are given by Matsubara (1943, p. 267, and following). *Thysanichthys* Jordan and Starks, 1904, (the other genus in the subfamily containing species with 13 dorsal spines) differs most noticeably in having palatine teeth.

The characters used to distinguish from *Scorpaenodes* some of the nominal genera listed in the synonymy have not proved to be of generic importance in other scorpaenid groups, but rather are species' differences. Some of the characters will distinguish groups of species, but only in one geographic area.

Species of the genus *Parascorpaenodes* were separated from *Scorpaenodes* by Smith (1957, p. 62) on the basis of having fewer scales (about 30 vertical scale rows rather than more than 35), the posterior part of the lateral line irregular, and the head more completely scaled. The scalation of the head is as complete in some other species which do not share the first two characters. The lateral line is complete (except where scales have been rubbed off) in specimens available to me, but the orientation of some of the posterior lateral line scales is slightly irregular. Species referred to the nominal genus *Hypomacrus* approach in scale size those of *Parascorpaenodes,* but scale size seems not to be a generic character.

Paronescodes was separated from *Scorpaenodes* by Smith (1958, p. 177) on the basis of more spines on the suborbital ridge, more scales on the body, and a more robust body; each of these conditions is found in some species referred to other nominal genera when the species are considered on a world basis.

The species of the nominal genus *Hypomacrus* differ in having some of the middle pectoral rays elongate and in lacking nasal spines. Elongate middle pectoral rays occur in some other species but not quite to the extent as present in the two or three species referable to *Hypomacrus*. The absence of nasal spines does not seem to be a generic difference, but corresponds to a general reduction of armature in these species. Unless other differences are found, the species previously referred to *Hypomacrus* should be considered only as a species group within *Scorpaenodes*.

The genus *Metzelaaria* was proposed by Jordan (1923, p. 209) for the western Atlantic species *tredecimspinosus* Metzelaar. This species has long been recognized as a *Scorpaenodes*.

Distinguishing features. Thirteen dorsal spines, none especially elongate; procurrent rays of the caudal fin unsegmented and spinous; no palatine teeth; gas bladder present.

Description. Dorsal rays normally XIII, 8–9 (XII–XIV, 8–10), last soft ray double. Anal rays normally III, 5 (4–6), last soft ray double. Pectoral rays 15–20, some rays branched except in juveniles. Procurrent caudal rays unsegmented and spinous. Teeth on vomer; none on palatines. Scales on body ctenoid, sometimes cycloid ventrally; head usually scaled. Vertebrae normally 24. Occipital pit absent. Third suborbital bone absent; fourth suborbital bone present, but isolated, in species examined; fifth suborbital bone attached to sphenotic. Second suborbital bone uniform or gradually becoming wider posteriorly, firmly and broadly attached to preopercular margin. First three interneurals fitting between the second and third neural spines. Preorbital bone with three lobes (Matsubara's terminology), the second and third lobes (lying over the maxillary) usually rounded but sometimes as broad spinous points. Suborbital ridge with spinous points (sometimes only one at end); some species with additional suborbital spines below the main ridge. Preopercular bone with supplemental spine usually present; first, second, and third preopercular spines present, second sometimes reduced or absent; fourth and fifth preopercular spines present or absent. Two ridges usually present between orbits and sometimes ending in spines (coronal spines of Smith, 1957, but not of Matsubara, 1943; interorbital spines of Ginsburg, 1953). Postfrontal spines often present. Additional spines below parietal spines sometimes present. Other spines include nasal (absent in species previously referred to *Hypomacrus*), preocular, supraocular, postocular, tympanic (frontal spines of Ginsburg), parietal, nuchal (posterior parietal spines of Ginsburg), sphenotic (usually as a group of points), pterotic, upper and lower posttemporal, opercular, supracleithral, and cleithral; occasionally additional spinous points present on head. Small slit behind fourth gill arch small or absent. Gas bladder present.

Scorpaenodes muciparus (Alcock)

(Figure 1a, b; table 1.)

Sebastes muciparus Alcock, 1889, pp. 298–299, fig. 3 on pl. 22 (original description; type locality Bay of Bengal, 26 miles N. by E. of Gopalpur, in 45 fathoms). Alcock, 1898, pl. 18, fig. 5 (good illustration). ?Weber, 1913, p. 491 (brief description; one from *Siboga* station 306, Solor Straits, 8°27′ S., 122°54′ W., in 247 meters).

?*Scorpaenodes muciparus*, de Beaufort *in* Weber and de Beaufort, 1962, pp. 34–35 (redescription of *Siboga* specimen described by Weber).

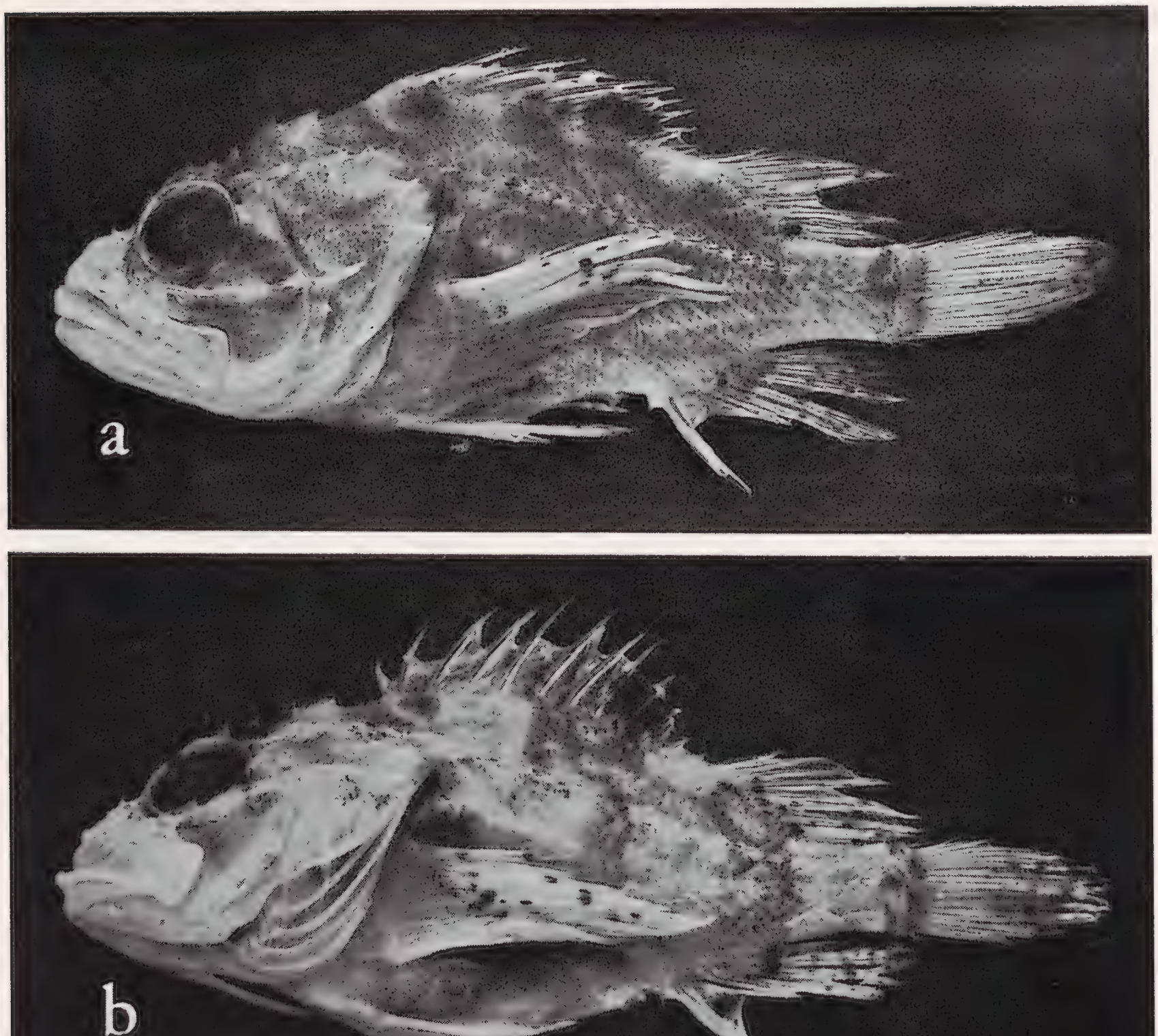
Scorpaenodes varipinnis Smith, 1957, p. 65 (in part; only the 50-mm. specimen taken from the stomach of a specimen of *Pristipomoides microlepis* collected in 110 fathoms off Memba and tentatively referred to *S. varipinnis;* differences in color pattern and habitat between this specimen and *S. varipinnis* discussed).

Remarks. The specimen collected by the *Siboga* (Weber, 1913) and redescribed by de Beaufort (Weber and de Beaufort, 1962) is very doubtfully a specimen of *S. muciparus*. The descriptions of the *Siboga* specimen lack sufficient information to allow definite identification, and I am not certain if it is even a specimen referable to *Scorpaenodes*. The specimen is larger in total length than any known specimen in the genus by about 50 millimeters. Branched pectoral rays are given as 4 by de Beaufort, but the specimen should have 7 or 8 branched rays if it is *S. muciparus*. Measurements are difficult to compare because of the great difference in size between the *Siboga* specimen and the other known specimens. Neither Weber nor de Beaufort mention if the procurrent caudal rays are spinous in the *Siboga* specimen.

Material examined. All specimens are from *Anton Bruun* cruise 4B: CAS no. 24264, (1, 71.2 mm.), station 279B, West Pakistan, 24°13′ N., 65°52′ E., in 93 fathoms, 9 December 1963; CAS no. 24265 (2, 45.8–48.9 mm.) station 221A, off western India, 22°32′ N., 68°07′ E., in 31.5 fathoms, 18 November 1963; CAS no. 24266 (1, 87.4 mm.) station 264A, Gulf of Oman, 25°02′ N., 56°52′ E., in 159 fathoms, 2 December 1963; USNM no. 204030 (1, 72.4 mm.) station 202A, off western India, 17°25′ N., 71°39′ E., in 52.5 fathoms, 13 November 1963.

Description. See also generic description. Measurements and counts summarized in table 1; body shape and color pattern in figure 1a, 1b.

Dorsal fin XIII, 9 (one specimen with XII, 10), last soft ray double. Anal fin III, 5, last soft ray double. Pectoral rays usually 19 (18–20), rays two or three through nine or ten branched in larger specimens; pectoral fin reaching to over anal soft rays. Spines on head well developed. Preorbital bone with second and third lobes each as a broad spinous point extending over the maxillary (third lobe with additional small points in larger specimens); suborbital ridge with one row of spinous points, one or more points on preorbital bone and three or more points on the suborbital bones. Interorbital ridges poorly developed, not ending in spines. Small spines (the postfrontal spines of Smith) near midline between tympanic spines usually absent (one spine in this area in two specimens). First preopercular spine long, second small and closer to first than to third, fourth broad, fifth absent; supplemental preopercular spine present. Upper posttemporal spine small or absent. Supracleithral spine double, upper part about one-half length of lower. Preocular, supraocular, and postocular spines well developed (supraocular spine double on left side of largest specimen). Small spine below parietal spine usually absent. Nasal spines present. Other spines as for the genus. Fourth suborbital bone isolated, bearing a few small spines (Ginsburg's postorbital spines). Tentacles and other fleshy skin appendages few. Supraocular tentacle about one-half orbit diameter in small specimens, shorter proportionally in larger specimens. A few tabs on upper part of eye, one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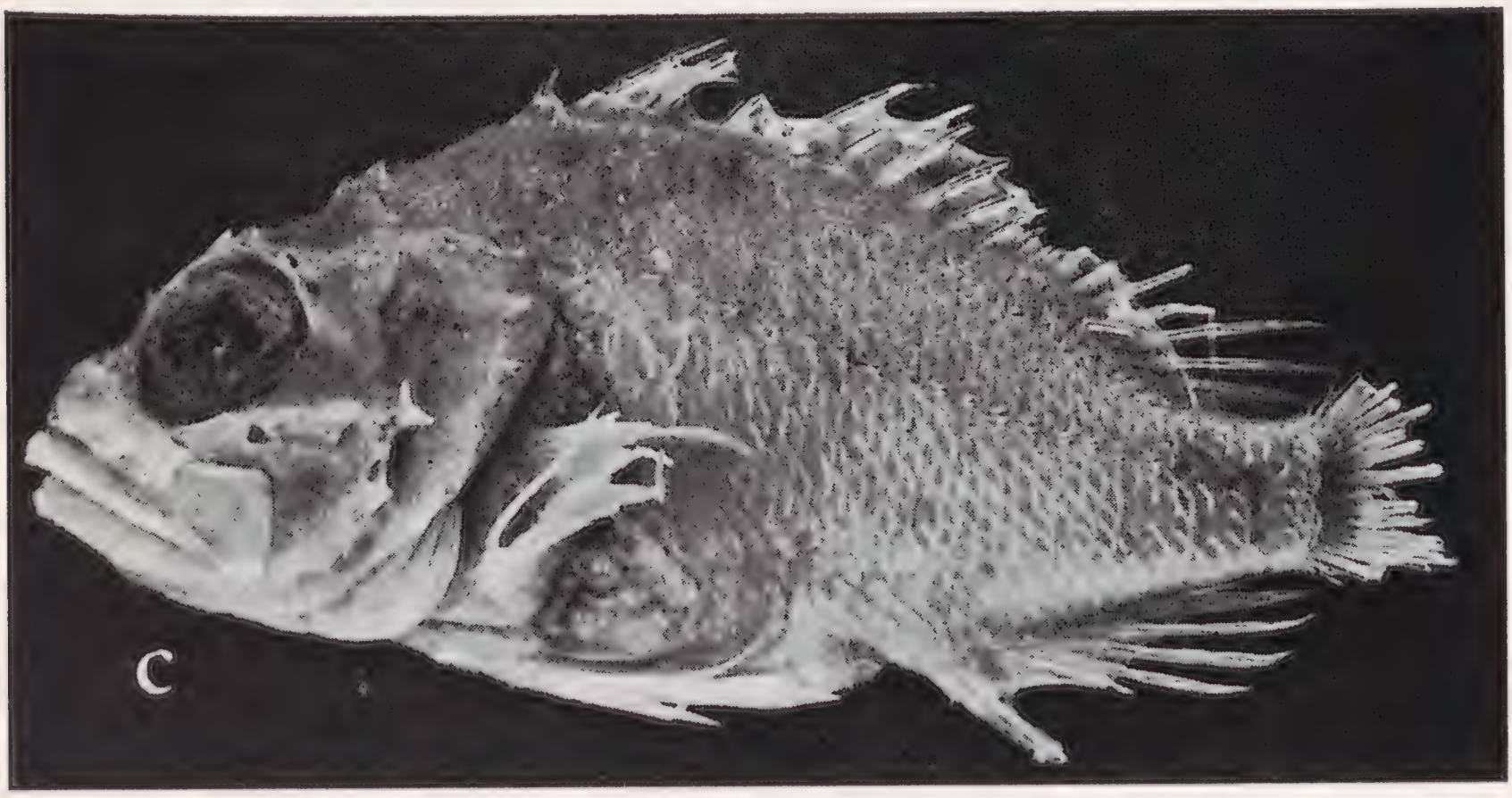
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TABLE 1. *Counts and measurements of specimens of* Scorpaenodes muciparus *and* S. tribulosus.

(Measurements are in millimeters; numbers in parentheses are percentages of standard length.)

	Scorpaenodes muciparus					*Scorpaenodes tribulosus*	
						Holotype	Paratype
Standard length	71.2	87.4	72.4	48.9	45.8	51.4	37.4
Dorsal fin rays	XII,10	XIII,9	XIII,9	XIII,9	XIII,9	XIII,8	XIII,8
Anal fin rays	III,5	III,5	III,5	III,5	III,5	III,5	III,5
Pectoral fin rays	19,20	19,18	19,19	19,19	19,19	19,19	19,19
Vertebrae	24	24	24	24	24	24	—
Gill rakers: left	6+13	6+14	6+12	6+12	6+12	5+9	5+10
right	6+11	6+13	6+13	6+12	6+12	5+8	5+10
Head length	34.8(49)	41.8(48)	37.2(51)	23.6(48)	21.5(47)	23.5(45)	17.1(45)
Snout length	8.1(11)	9.4(11)	8.0(11)	5.7(12)	4.9(11)	5.8(11)	4.3(12)
Orbit diameter	9.6(13)	11.3(13)	9.5(13)	6.8(14)	5.9(13)	7.5(15)	4.9(13)
Interorbital width	4.8(07)	5.1(06)	4.6(06)	2.9(06)	2.3(05)	3.4(07)	2.7(07)
Upper jaw length	16.7(23)	20.5(23)	16.6(23)	11.5(24)	10.2(22)	12.5(24)	8.9(24)
Predorsal-fin length	30.6(43)	36.8(42)	31.3(43)	21.6(44)	19.4(42)	23.1(45)	16.2(43)
Body depth	28.4(40)	32.3(37)	27.8(38)	20.0(41)	17.9(39)	23.2(45)	15.6(42)
Pectoral fin length	24.9(35)	32.4(37)	26.1(36)	17.6(36)	17.0(35)	—	12.6(34)
Pelvic fin length	18.1(24)	22.1(25)	18.5(26)	13.4(27)	12.5(27)	12.5(24)	10.3(28)
Caudal fin length	22.2(31)	27.8(32)	22.6(31)	15.1(31)	14.4(31)	—	11.1(30)

larger than the others. Dorsal and anal fin spines relatively long; length third dorsal spine 13–16 percent S.L., penultimate spine 5–8 percent, last spine 11–13 percent. Second anal spine longer than third, both ending at about the same point or second extending beyond third when depressed. Scales on flanks ctenoid; vertical scale rows about 50; lateral line scales about 23 plus 2 on caudal fin (many scales rubbed off in available specimens). Bases of fins with a few scales. Scales on chest and pectoral base cycloid. Dorsal parts of head scaled; underside of head unscaled or with cycloid scales. Gill rakers including rudiments 18–20; upper arch with 6 short spiny rakers; lower arch with 9–10 rakers on ceratohyal and 2–5 flat rudiments on hypohyal. Small slit present behind fourth gill arch. Color pattern as in figure 1a, 1b. The dark pigment in smaller specimens most intense on pectoral fin and as a spot on the spinous dorsal fin.

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FIGURE 1a. *Scorpaenodes muciparus*, CAS no. 24266, 71.2 mm. S.L., off West Pakistan, 24°13′ N., 65°52′ E., in 93 fathoms; 1b. *Scorpaenodes muciparus*, CAS no. 24265, 48.9 mm. S.L., off western India, 22°32′ N., 68°07′ E., in 31.5 fathoms; 1c. *Scorpaenodes tribulosus*, CAS no. 24267, holotype, 51.4 mm. S.L., off Kenya, 02°42′ S., 40°53′ E., in 77 fathoms.

Comparisons. Most species of the genus are reef inhabitants occurring in very shallow water, but the present species and *Scorpaenodes tribulosus* appear to be exceptions. *Scorpaenodes muciparus* has been taken in depths from 31–159 fathoms and *S. tribulosus* from 77 and 40 to 96 fathoms. *Scorpaenodes tredecimspinosus* from the western Atlantic has been collected from as deep as 50 fathoms, but it usually occurs in depths from 10–20 fathoms. Other species of the genus are shore forms which rarely descend below about 10 fathoms.

Groups of species of *Scorpaenodes* differ from *S. muciparus* in lacking a spot on the spinous dorsal fin, having shorter dorsal spines, having extra spines below the suborbital ridge, having spines on the interorbital ridges, lacking nasal spines, having fewer scales, and having eight rather than nine soft dorsal rays. Most of the shallow-living species are characteristically brightly colored.

The specimen tentatively referred to *S. varipinnis* by Smith (1957, p. 65) is a specimen of *S. muciparus*. *Scorpaenodes muciparus* differs from *S. varipinnis* in having normally nine rather than eight soft dorsal rays, more spines on the suborbital ridge (usually one on preorbital and three or more on suborbitals versus one plus two), and smaller scales. The color pattern and depth of capture of Smith's specimen also agree with *S. muciparus*. *Scorpaenodes muciparus* is compared with *S. tribulosus* under the account of *S. tribulosus*.

Distribution. *Scorpaenodes muciparus* is known from the type collected in the Bay of Bengal and from the five specimens described here which were collected in the Gulf of Oman and in the Arabian Sea off western India and West Pakistan. The specimen reported on by Smith (1957, p. 65) was taken off Memba, Mozambique. Depths of capture range from 31 to 159 fathoms.

Scorpaenodes tribulosus Eschmeyer, new species.

(Figure 1c; table 1.)

Holotype. CAS no. 24267, a specimen 51.4 mm. in standard length, *Anton Bruun* cruise 8, station 420A, off Kenya, 02°42′S., 40°53′E., in 77 fathoms, field no. LK 64-101, 6 November 1964.

Paratype. USNM no. 204031 (1, 37.4 mm.) *Anton Bruun* cruise 9, station 463, off Somali Republic, 11°24′N., 51°35′E., in 40–96 fathoms, 17 December 1964.

Description. See also generic description. Measurements and counts summarized in table 1; body shape and color pattern in figure 1c.

Dorsal fin XIII, 8, last soft ray double. Anal fin III, 5, last soft ray double. Pectoral rays 19, some rays branched (rays broken distally in holotype; paratype with rays 3–9 or 10 branched, second rays broken; probably rays 2 through 9 or 10 usually branched in specimens of this size); pectoral fin reaching to level of first anal spine. Spines on head fragile. Preorbital bone with second lobe as a broad rounded shelf and third lobe broad with two small points in

holotype and one point in paratype; several small spinous points on preorbital bone in front of eye. Suborbital ridge with 6–8 poorly defined spinous points in holotype and 4 in paratype. (Much variability is expected in suborbital spination; the usual condition is probably one spine on the preorbital in line with three on the suborbitals; the condition in the holotype represents a splitting of some of these.) A strong ridge on anterior margin of pore between first and second suborbital bones. Interorbital ridges poorly developed, ending in small upright spines (coronal spines of Smith) in holotype and absent in paratype (variable in other species also). No postfrontal spines near midline between the tympanic spines (usually variable in other species). Preopercular spines fairly small; supplemental and five preopercular spines present; second preopercular spine slightly smaller than first or third and closer to first. Upper posttemporal spine small or absent. Supracleithral spine double, upper part about one-half length of lower part. Spine below parietal spine absent. Nasal spines present. Fourth suborbital bone isolated, with low spinous points (postorbital spines of Ginsburg). Other spines as for the genus. Skin appendages poorly developed. Supraocular tentacle less than one-half orbit diameter. Dorsal and anal fin spines relatively long; length third dorsal spine 17 percent S.L. (paratype), penultimate 4 percent (paratype), last spine broken in both specimens. Second anal spine about equal to or slightly longer than third, second extending beyond third when depressed. Scales on body strongly ctenoid. Vertical scale rows about 45 (some scales rubbed off in available specimens). Bases of fins with ctenoid scales. All of head, including nape, interorbital area, edge of eye, jaws, and underside of head with small ctenoid scales. Scales on chest and pectoral-fin base mostly ctenoid. Gill rakers including rudiments 14–15; upper arch with 5 rakers; lower arch with 9 rakers on ceratohyal and 0–1 rudiment on hypohyal. Small slit present behind fourth gill arch. Body shape and color pattern as in figure 1c. Holotype mostly pallid, with a few dark specks on membranes between posterior dorsal spines. Paratype pallid except for dark spot between dorsal spines 8–11. A minute dusky tentacle at left nuchal spine in paratype. Head pores better developed than in other species of the genus, especially those pores associated with the preorbital bone, between the preorbital and first suborbital bone, and between first and second suborbital bones.

COMPARISONS. This species is characterized by the presence of extremely rough scales caused by numerous long ctenii, especially on the scales about the head. *Scorpaenodes parvipinnis* (Garrett, 1863) (= *Paronescodes asperrimus* Smith, 1958) also has strongly ctenoid scales, but the ctenii of scales in *S. tribulosus* are longer, and the degree of scalation on the underside of the head and on the maxillaries is stronger in *S. tribulosus*. The head pores appear to be proportionally larger in *S. tribulosus* than in other species of *Scorpaenodes* (larger pores are usually found in the deeper-living species of each genus). *Scorpaenodes tribulosus* agrees with *S. muciparus* in living in deeper water than other species

of the genus. *Scorpaenodes tribulosus* is most easily distinguished from *S. muciparus* in usually having 8 rather than 9 soft dorsal rays, and in having the underside of the head covered with ctenoid scales rather than being naked or covered with cycloid scales.

Distribution. The species is known from the two type specimens from off northwest Africa at Kenya and the Somali Republic in 77 and between 40–96 fathoms respectively.

Name. The species is named "*tribulosus*," the Latin word for thorny, alluding to the strongly ctenoid scales.

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Additional Records of *Tetrabalanus polygenus* Cornwall, 1941 (Cirripedia, Thoracica)

By

Victor A. Zullo

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Additional Records of *Tetrabalanus polygenus* Cornwall, 1941 (Cirripedia, Thoracica)

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ABSTRACT: The four-plated balanid barnacle *Tetrabalanus polygenus* Cornwall, 1941, unreported since its original description from Puna Island, Gulf of Guayaquil, Ecuador, is recorded from the Guayas River estuary at Guayaquil, Ecuador, Santa Elena Bay, Ecuador, and Puntarenas, Costa Rica. The latter occurrence increases the known range of this monotypic genus over 12.5° of latitude to the north, and suggests a wide distribution for the species in the Panamic Province. Although capable of living in waters of normal marine salinities, *Tetrabalanus polygenus* appears to prefer estuarine conditions commonly associated with typical mangrove facies.

INTRODUCTION

The unusual porose-walled, four-plated balanid *Tetrabalanus polygenus* Cornwall, 1941 has not been reported since its original description from shore localities on Puna Island in the Gulf of Guayaquil, Ecuador. Four additional lots have now been uncovered that provide supplementary data on morphology, geographic distribution, and ecology of this species.

The first lot to come to my attention was obtained by Mr. Robert Schuster, University of California at Davis, on 5 March 1964 during the 1964 Galápagos International Scientific Project. Six large individuals were taken from a moderately dense population at mid-tide on dock pilings at Porto Nuevo, Guayaquil in the Guayas River estuary (California Academy of Sciences (CAS) locality 40748). Two additional lots were uncovered in the following year at the Academy of Natural Sciences of Philadelphia (ANSP). One, consisting of four specimens from Santa Elena Bay, Ecuador, had been donated by Herbert N. Lowe in 1933 (ANSP cat. no. 2602). The second, of six individuals, was taken on the oyster *Ostrea* (*Crassostrea*) *columbiensis* Hanley, 1846, attached to mangroves on the mud flats along the Estero at Puntarenas, Costa Rica, by George

and Mary Kline in January, 1966 (ANSP catalog number 7302). A fourth lot of over 50 specimens was found on two shells of *Ostrea columbiensis* in the collection of the California Academy of Sciences (CAS locality 28027). The oysters, from mangrove roots in Santa Elena Bay, Ecuador, were donated by Herbert Lowe in 1934, and probably represent the same collection as that of ANSP catalog number 2602.

Morphology

Shell (figs. 5–6, 11–12). Many of the specimens on hand are larger than those of the type lot. The largest, from the dock at Guayaquil, is 24 millimeters in carinorostral diameter, and most of the others from that locality are 20 millimeters in diameter, or at least twice the diameter of the largest type lot individual. A conspicuous yellow to dirty-brown epidermis covers at least the lower half of the shell in most specimens. The radii vary somewhat in width, but always have steeply oblique summits and thick sutural edges whose septa are denticulate on their lower sides. The alae are short with gently sloping summits that project above the radii. The sheath is short, but usually hangs free, leaving a space under its lower edge. The numerous parietal tubes are square to rectangular in outline when viewed basally, tend to be filled in their upper parts, and are crossed by transverse septa for most of their remaining length. The basal edge of the outer lamella of the shell wall bears minute, regularly spaced denticulae and, usually, one to three large secondary septa that project into the parietal tubes, but do not reach the inner lamella. These secondary septa are denticulate basally and form part of the articulation between shell wall and basis.

Scuta (figs. 1, 3, 8, 9). The exterior of the scutum is concave between basal margin and apex, and is covered with a thick, yellow-brown epidermis. Underneath, the scutum is tricolored, with a broad central band of purple-pink flanked by narrow white stripes on the occludent and tergal margins. The growth lines are irregular, but not prominent and are crossed by faint radial striations. The articular ridge is short, being roughly half the length of the valve, but quite prominent and reflexed over the deep articular furrow. The prominent adductor ridge is short, centrally located on the valve, and parallel to the occludent margin. It overhangs a large, deep, triangular pit that extends

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Figures 1–4. Opercular valves of *Tetrabalanus polygenus* Cornwall, hypotype CAS 13148, CAS locality 40824, Ecuador. Figure 1, exterior of scutum showing color pattern, height 6 mm.; figure 2, exterior of tergum, height 5.6 mm.; figure 3, interior of scutum, height 6 mm.; figure 4, interior of tergum, height 5.6 mm.

Figures 5, 6. Shells of *Tetrabalanus polygenus* Cornwall, CAS locality 40824, Ecuador. Figure 5, basal view showing details of septation, hypotype CAS 13152, greatest diameter of base 21 mm.; figure 6, rostrum with outer lamella removed to show transverse septa of parietal tubes, hypotype CAS 13151, greatest width of plate 15 mm.

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upward beneath the arch formed by the confluence of the upper end of the adductor and the lower end of the articular ridges. The adductor pit is large and deep. In young specimens there is little or no indication of a lateral depressor muscle pit, but in larger ones a small shallow pit is found at the basiscutal angle. In all specimens examined, a low ridge extends from the base of the articular ridge along the occludent border of the lateral depressor muscle pit area to the basal margin, forming an elongate triangular hollow between it and the reflexed tergal margin of the valve. The apical part of the interior of the scutum is conspicuously roughened and ridged.

Terga (figs. 2, 4, 7, 10). The exterior of the tergum also has a thick epidermal covering. The cleaned valve is white with a suffusion of pink on the carinal half. The spur furrow is open throughout its length, but well marked by grooves on either side. The tergal spur is about one-fifth the height of the valve and occupies one-fourth to a little less than one-third the basal margin. It is rounded basally and placed close to the basiscutal angle. The articular ridge is low and erect and does not curve basally towards the scutal margin. The articular furrow is correspondingly shallow and broad. Lateral depressor muscle crests are numerous and prominent and project below the basal margin of the valve. The carinal side of the interior of the tergum is roughened and ridged.

Mouthparts (figs. 13–18). Two individuals, one from Guayaquil (CAS locality 40748) and the other from Puntarenas (ANSP cat. no. 7302) were dissected for comparison with the type description. The labra are deeply notched and the number of teeth on the crest is variable. The Puntarenas specimen has three on either side, whereas that from Guayaquil has two on the right and none on the left. The mandibles have three large upper teeth, the second being bifid, and two smaller molariform teeth below. The superior and inferior margins are setose. The first maxillae have straight margins except for the lower third which is slightly protrudent. There is no notch below the two large upper spines. The central third bears seven or eight slender spines, followed on the protrudent third by two large spines and several short spinules at the inferior angle. The superior and inferior margins are setose. The second maxillae are ovate, bilobed, and densely setose.

Cirri (figs. 19–23). The outer (anterior) ramus of cirrus I is antenniform and at least half again as long as the inner ramus. The lower articles of the

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Figures 7–10. Opercular valves of *Tetrabalanus polygenus* Cornwall, ANSP cat. no. 7302, Costa Rica. Figure 7, interior of tergum, height 5.5 mm.; figure 8, interior of scutum, height 6 mm.; figure 9, exterior of scutum, height 6 mm.; figure 10, exterior of tergum, height 5.5 mm.

Figures 11, 12. Shells of *Tetrabalanus polygenus* Cornwall. Figure 11, group of shells on *Ostrea columbiensis* Hanley showing epidermis, hypotype Lot CAS 13149, CAS locality 28027, Ecuador, length of oyster 56 mm.; figure 12, dorsal view of largest shell, hypotype CAS 13150, CAS locality 40824, Ecuador, carinorostral diameter 24 mm.

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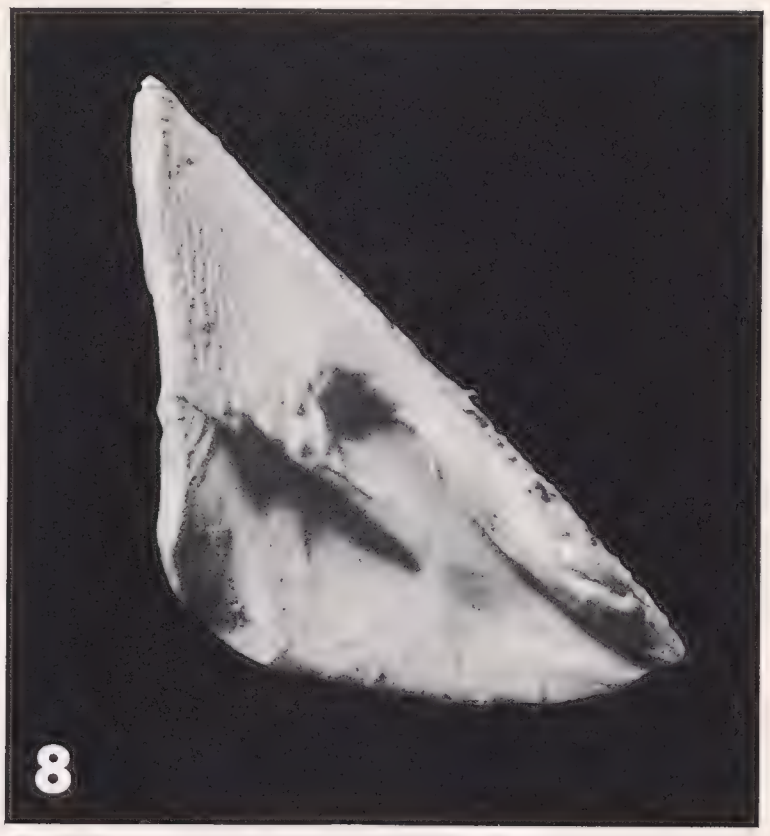
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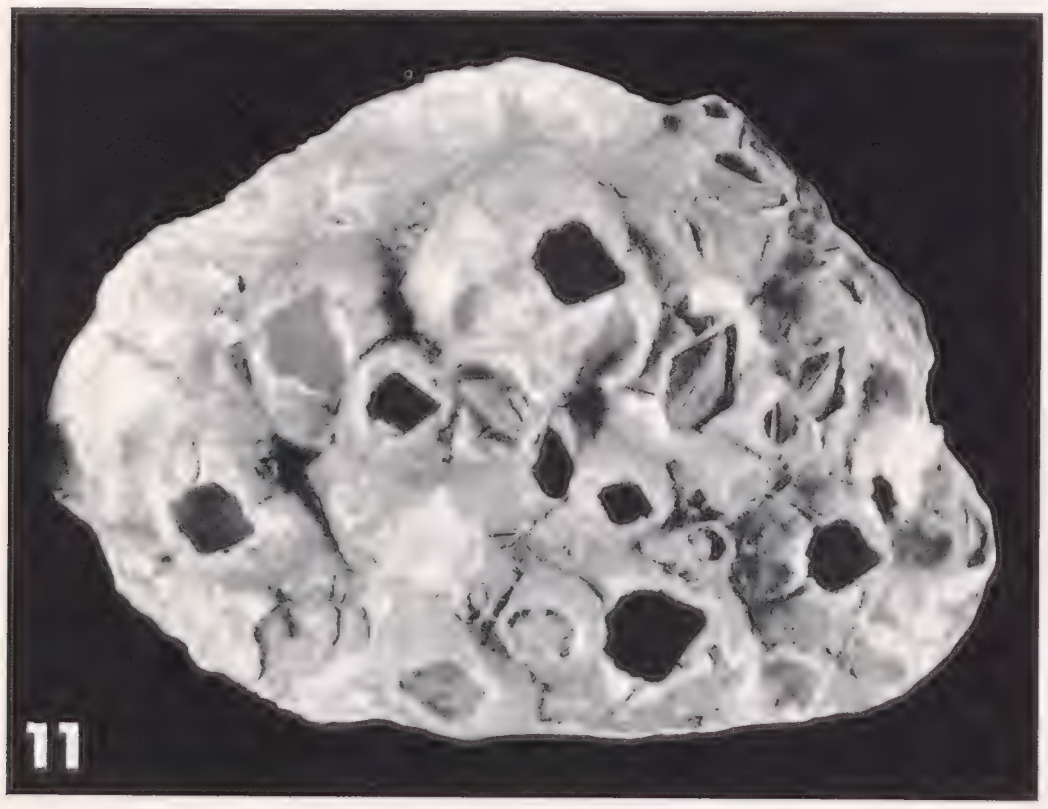
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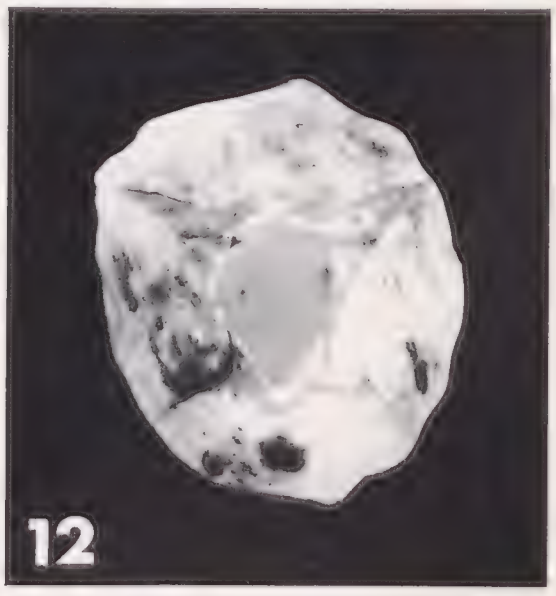
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inner ramus are protuberant and densely setose, whereas the distal articles are sparsely setose and attenuate. The rami of cirrus II are short, broad, of nearly equal length, and have densely setose, protuberant articles. The nearly equal rami of cirrus III are short, but longer and more slender than those of cirrus II, and without protuberant articles. The articles of the lower half of each ramus bear numerous small teeth scattered over their anterior faces, and one to four upwardly recurved teeth near the distal posterior edge. Cirri IV–VI are slender and elongate, and the articles of the lower half of each ramus bear a single upwardly recurved tooth at the distal posterior edge. The median articles of cirrus VI have up to seven pairs of spines.

Ecology and Distribution

Although salinity data for the localities described herein were not available to me, the records suggest that *T. polygenus* is a euryhaline species that may prefer brackish environments. With the exception of the type lot from shore rocks in apparently marine waters, all localities indicate lowered salinity conditions for at least part of the year. The Guayas River locality is 48 kilometers from the sea, and the Santa Elena and Puntarenas specimens appear to be associated with typical brackish mangrove facies.

The presumed brackish water representatives of this species differ from the type lot in their larger average size and in their possession of an epidermal covering. Parallel situations can be found in other euryhaline species such as *Balanus eburneus* Gould, 1841, and *B. improvisus* Darwin, 1854, on the East Coast of North America. Individuals living in estuaries (15–20‰) attain greater average size and possess a more conspicuous epidermis than do those in normal marine environments (30–34‰). This greater development of epidermis may be a response to the effects of lowered pH in brackish water on shell dissolution.

The occurrence of *Tetrabalanus polygenus* at Puntarenas, Costa Rica, increases the known range of this species over 12.5° of latitude to the north, and suggests that it is widely distributed in the Panamic Province. Although the barnacles of this province are poorly known, it is unusual that more specimens of *T. polygenus* have not been encountered in museum collections. If, however, this species is usually associated with brackish mangrove facies, its absence in collections is more easily understood, as most marine invertebrate collecting in the Panamic Province has been directed at the normal marine environment.

→

Figures 13–19. Mouth parts and Cirrus II of *Tetrabalanus polygenus* Cornwall. Figure 13, mandible; figure 17, labrum; figure 19, Cirrus II, hypotype CAS 13148, CAS locality 40824, Ecuador, × 30. Figure 14, mandible, × 30; figures 15, 16, maxilla I, × 45; figure 18, labrum, × 30, ANSP cat. no. 7302, Costa Rica.
(Prints by G Dallas Hanna)

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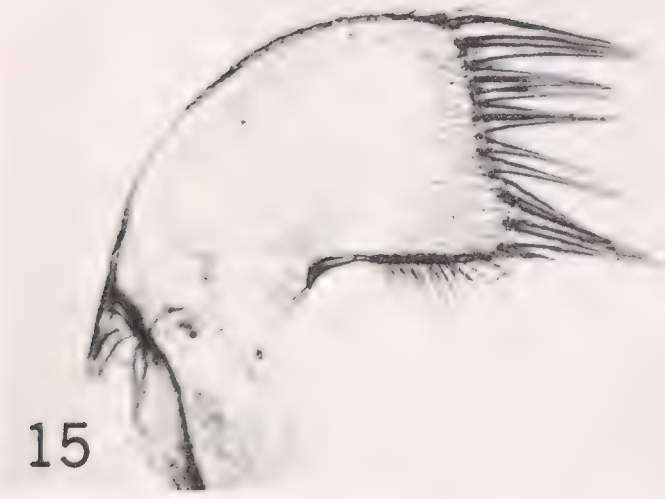
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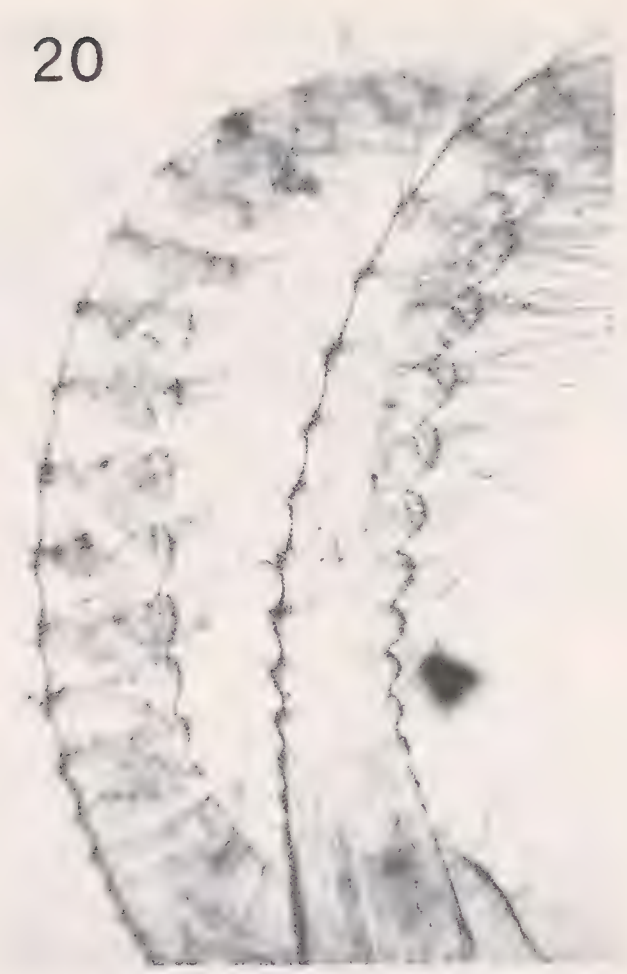

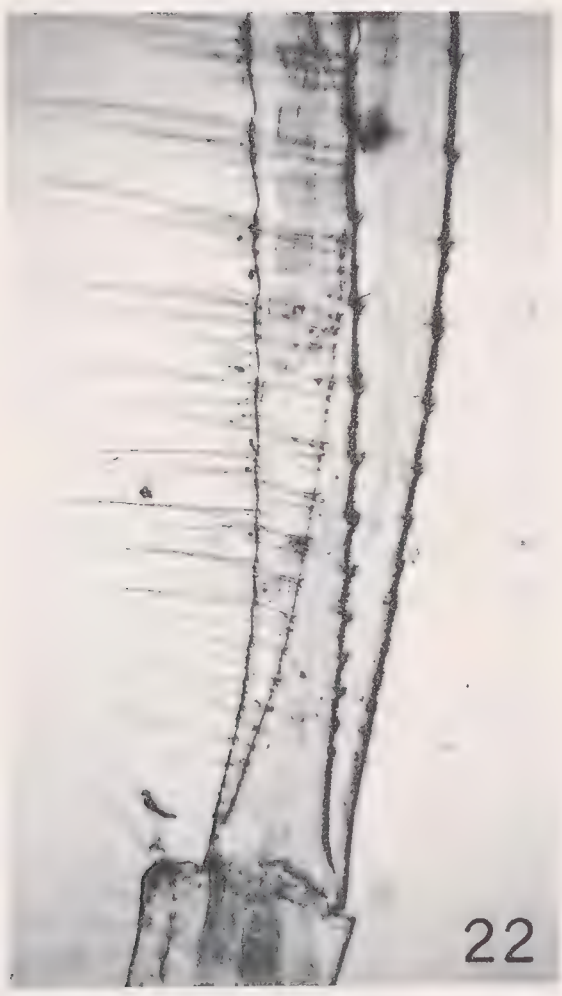

Figures 20–23. Details of cirri of *Tetrabalanus polygenus* Cornwall, × 30. Figure 20, Cirrus III; figure 21, Cirrus IV; figure 22, Cirrus V, hypotype CAS 13148, CAS locality 40824, Ecuador. Figure 23, Cirrus VI, ANSP cat. no. 7302, Costa Rica.
(Prints by G Dallas Hanna)

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COMMITTEE ON PUBLICATION

Dr. George E. Lindsay, *Chairman*

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The gonozoids are short; 210 to 220 microns in length, with the tip of the degenerate polypide extending below the embryo chamber.

OCCURRENCE. Pokai Bay, 0.5 miles off Waianae, Oahu; depth 25 feet. Collected 26 July 1967 in shell of *Conus* species. Off Naue, Kauai; depth 30 feet, water temperature 80°F., in shell of *Conus ebraeus*.

Penetrantia operculata Soule and Soule, new species.

(Figures 2, 3[3], 4, 5, 12, 13.)

MATERIAL. Holotype, Allan Hancock Foundation bryozoan number 150. Paratype, Allan Hancock Foundation bryozoan number 150.1.

DIAGNOSIS. Burrowing colonial ectoproct bryozoans with the autozoids and gonozoids connected by "stolons." Autozoids elongated, cylindrical, bluntly rounded proximally, and with the aperture closed by a massive knobbed operculum. Tentacle number is 12. Gonozoids short, the degenerate polypide curled around under the embryo chamber.

DESCRIPTION. The colonies of *Penetrantia operculata* consist of feeding autozoids and numerous reproductive gonozoids. The mature functional feeding autozoids measure from 450 to 500 microns in length, and 100 to 110 microns in width. Each autozoid possesses a polypide bearing 12 tentacles and a typical U-shaped digestive tract. The digestive tract is provided with a small gizzard opening into the stomach. The muscular system consists of the retractor muscle group, scattered parietal muscle fibers, and the apertural muscle group. The aperture is closed by a distinctive thick operculum. Each operculum is provided with a centrally placed, raised knob.

The gonozoid is short, measuring 220 to 230 microns in length. It has a bulbous embryo chamber containing the ovum and a polypide that is curved, curling proximally under the reproductive body. The musculature and the polypide retrogress and are non-functional. The operculum is conspicuous, loosely associated with the degenerate polypide mass.

The openings on the surface of the mollusk shell, produced by the zoids of *Penetrantia operculata* are well spaced, almost circular, with a blunt projection extending into the opening from the lower rim. The aperture of the zoid proper

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FIGURE 6. *Terebripora varians*, new species; normal zoid.

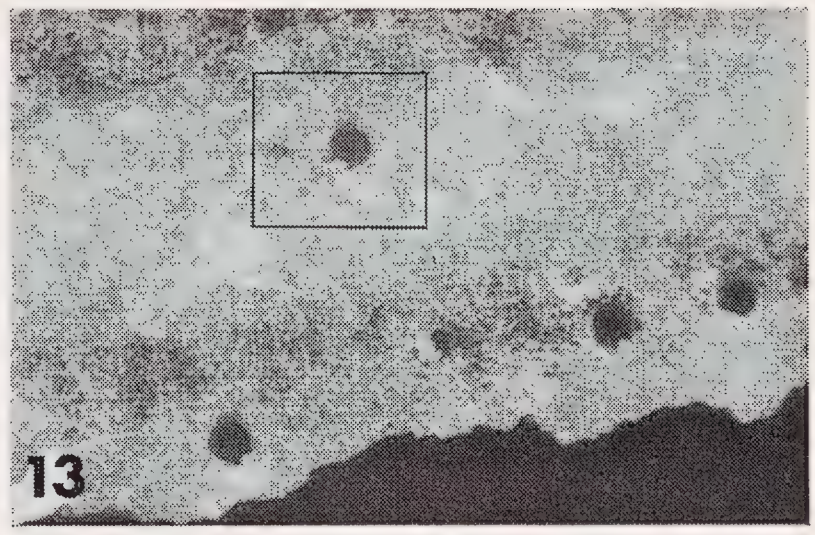
FIGURE 7. *T. varians*, new species; zoid in reproduction, with degenerate polypide, developing ovum, and brown body.

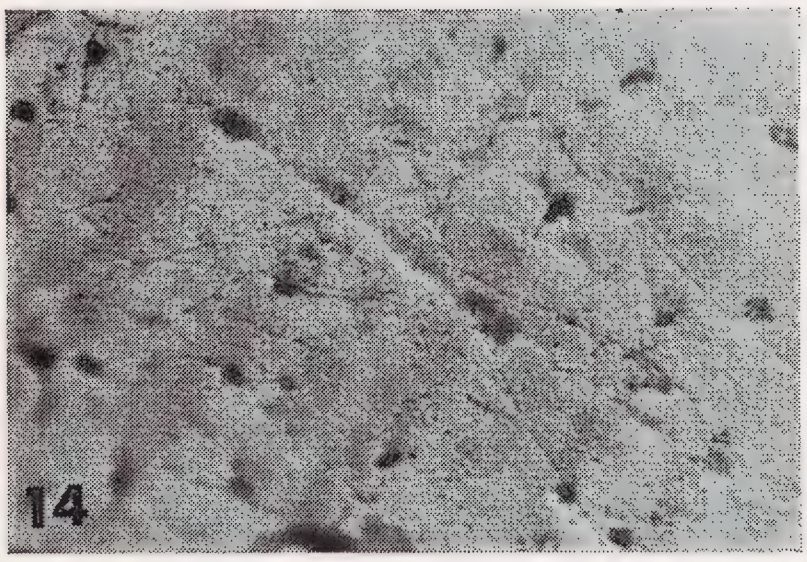
FIGURE 8. *T. varians*, new species; a, b, c, d, e, showing variety of stolon attachments on individuals.

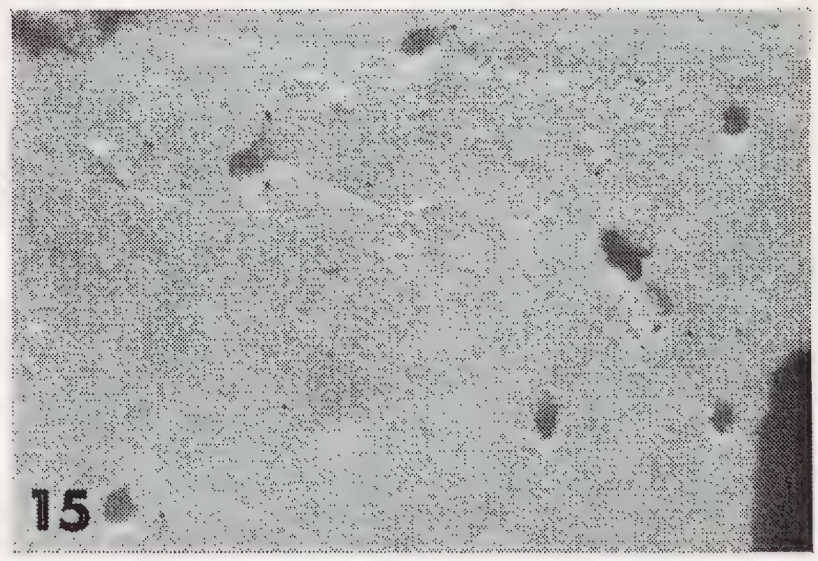
FIGURE 9. *Immergentia zelandica minuta* Soule; normal zoid.

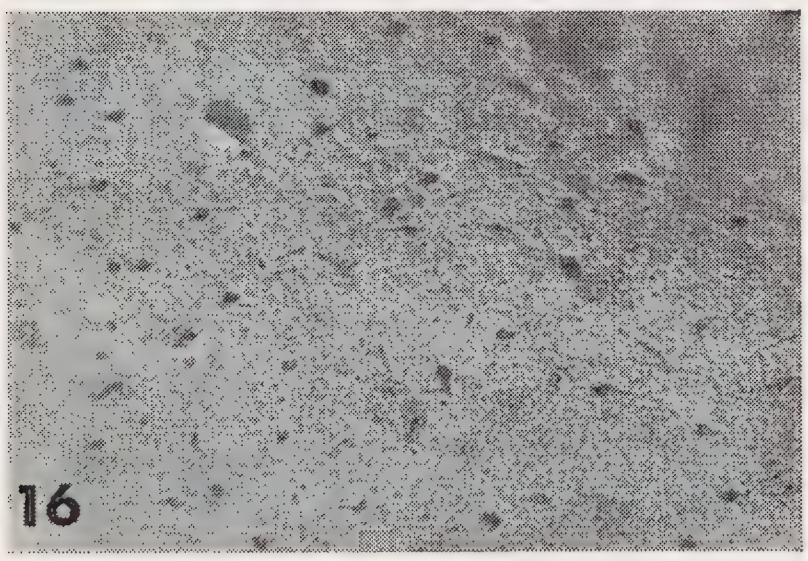
FIGURE 10. *Immergentia angulata*, new species; zoid angled away from viewer. Note size as compared with *Immergentia zelandica minuta*.

FIGURE 11. *I. angulata*, new species; zoid in reproduction.









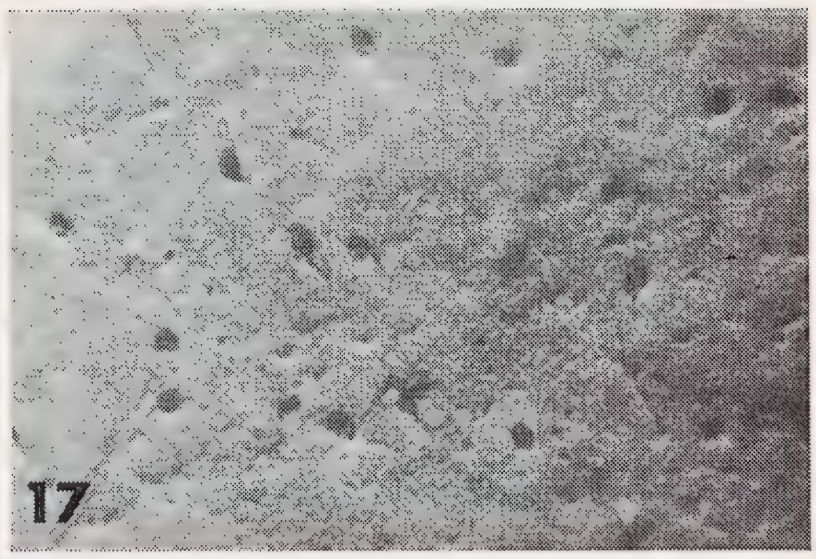


Figure 12. *Penetrantia operculata*, new species; apertures in shell, × 25.

Figure 13. *P. operculata*, new species; apertures in shell, showing submerged zoid aperture with median denticle and cardelles, operculum with knob, × 50.

Figure 14. *Terebripora varians*, new species; irregular shell apertures and stolon traces, × 25.

Figure 15. *T. varians*, new species; irregular apertures in shell, × 50.

Figure 16. *Immergentia angulata*, new species; apertures in shell and stolon traces, × 25.

Figure 17. *I. angulata*, new species; ovoid apertures in shell and short stolon traces, × 50.

lies below the shell surface and bears a prominent median denticle (lyrula), as well as lateral hinge denticles (cardelles) for articulation of the operculum. The stolonal tracings form an indistinct, irregular meshwork. The surface markings are similar to those of *Penetrantia concharum*, as illustrated by Silén, 1947 (fig. 1).

Penetrantia operculata differs from previously described species in that each of the autozoids possesses the thick, knobbed operculum, and the gonozoid bears the non-functional polypide flexed, curving under the embryo chamber. Autozoids of *P. operculata*, new species, *P. densa* Silén, 1946, and of *P. brevis* Silén, 1946, all have 12 tentacles.

Occurrence. Haena Bay, Kauai; collected 1 July 1967, depth 20 feet, water temperature 80°F. In shell of *Conus striatus*.

Genus **Terebripora** d'Orbigny, 1847

Terebripora varians Soule and Soule, new species.

(Figures 6^3, 7^3, 8a–e, 14, 15.)

Material. Holotype, Allan Hancock Foundation bryozoan number 151. Paratype, Allan Hancock Foundation bryozoan number 151.1.

Diagnosis. Stolonate, burrowing colonial Ectoprocta, with cylindrical zoids that taper to a narrow proximal end. The zoids are connected by short multiple secondary stolons that join the elongated primary stolons. There are 11 tentacles.

Description. Colonies stolonate, possessing lengthy primary stolons which have internodes placed at irregular intervals so that the stolonal segments are of variable length. The primary stolons anastomose to form an extensive meshwork. A notable feature of this species is the presence of multiple secondary stolons, up to 4 in number, which arise from diverse localities on a single zoid and unite with the primary stolon. The stolonal diameter ranges from 10 to 15 microns.

The polypide includes a digestive tract with a prominent grinding organ, or gizzard, and bears a circle of eleven tentacles. The musculature consists of the apertural group, the parietals, and the retractor group. The length of the functional zoids ranges from 370 to 400 microns, with the width from 60 to 75 microns. Many of the zoids possess one or more small "brown bodies." Zoids in reproduction were scarce: two were found, each with a rounded ovum and a degenerated polypide.

Surface tracings on the mollusk shell formed by the zoid apertures and stolons of *Terebripora varians* are not distinctive. The openings are well spaced, and are irregularly ovoid. The stolons produce a faint mesh-like trace among and connecting the rounded perforations.

Terebripora varians differs from other species of *Terebripora* with known anatomy in the possession of multiple secondary stolons which arise from varying

anatomical areas on the zoid. It is this character that provides its name. The zoids of *Terebripora varians* are larger than those of *T. comma* and *T. ramosa*, but smaller than those of *T. eltaninae*. *Terebripora varians* has 11 tentacles, *T. comma* has 8 tentacles, *T. ramosa* has 12 tentacles, and *T. eltaninae* has 10 tentacles.

Occurrence. Haena Bay, Kauai; collected 1 July 1967, depth 20 feet, water temperature 80°F., in shells of *Conus striatus*. Off Keaukaha, Hilo, Hawaii; collected 15 July 1967, depth 25 feet, water temperature 81°F., in shells of *Conus* species?.

Genus **Immergentia** Silén, 1946

Immergentia zelandica minuta Soule, 1950.
(Figure 9[3].)

Immergentia zelandica Silén var. *minuta* Soule, 1950, p. 367, fig. 6.

Colonies with small zoids, ranging in length from 210 to 250 microns, slightly longer than those from the Philippine Islands. A distinct, finger-like projection is present, forming the proximal extremity. There are 9 tentacles. A number of zoids with an ovum and degenerate polypide were present.

Occurrence. Haena Bay, Kauai; collected 1 July 1967, depth 20 feet, water temperature 80°F., in shells of *Conus striatus* and *Cypraea* species?.

Immergentia angulata Soule and Soule, new species.
(Figures 10, 11, 16, 17.)

Material. Holotype, Allan Hancock Foundation bryozoan number 152. Paratype, Allan Hancock Foundation bryozoan number 152.1.

Diagnosis. Colonial, stolonate burrowing ectoproct bryozoan. Zoids extremely small, acutely curved at the distal end below the aperture, and tapering to a pointed proximal termination. The tentacle number is 8.

Description. Colonies are stolonate, with the zoids joined by an irregular anastomosing meshwork of delicate hollow stolons having a diameter of 7–8 microns. Functional zoids are short, ranging from 180 to 200 microns in length and 50 to 55 microns in width. The zoids characteristically are bent acutely in the distal region immediately below the junction of the apertural region with the stolon. The proximal extremity is tapered to a point. In functional zoids the polypide is U-shaped. There are 8 tentacles. "Brown bodies" are present in many of the zoids. The musculature consists of a well developed retractor group, parietals, and an apertural group. Zoids with developing ova and a degenerate polypide were scattered among the feeding zoids. The musculature, especially in the retractor group, shows evidence of hypertrophy in the zoids with reproductive bodies.

The openings made by the zoids are very small. They are ovoid, narrowing toward the thread-like trace made by the stolon. The openings are well spaced.

They offer no special characteristics that would distinguish them from other species of *Immergentia* or even from *Terebripora*.

Immergentia angulata possesses zoids that are the smallest of any that have been described, and are the only ones to show the acute bend at the distal end. Also, in having 8 tentacles, *I. angulata* differs from *Immergentia californica* Silén, 1946 and *I. philippinensis* Soule, 1950, which have 10 tentacles, and *I. suecica* Silén, 1947, *I. zelandica* Silén, 1946, and *I. zelandica minuta* Soule, 1950 with 9 tentacles.

OCCURRENCE. Keaukaha, Hilo. Hawaii; collected 15 July 1967, depth 45 feet, water temperature 81°F., in shell of *Pisania tritonoides*.

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OCCASIONAL PAPERS

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No. 79, 130 pages, 13 figures, 15 tables. December 26, 1969

A Systematic Review of the Scorpionfishes of the Atlantic Ocean (Pisces: Scorpaenidae)

By

William N. Eschmeyer

California Academy of Sciences
San Francisco, California 94118

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A Systematic Review of the Scorpionfishes of the Atlantic Ocean (Pisces: Scorpaenidae)[1]

By

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Introduction

The scorpionfishes, family Scorpaenidae, comprise a diverse group of about 350 valid species. The family is best represented in shallow waters of tropical seas, but important groups occur at high latitudes, particularly in the North Pacific Ocean; the greatest diversity is present in the tropical waters of the Indo-Pacific. Besides the commercially important species, some fishes of the family have received much attention because of the presence of toxic substances associated with fin spines. Despite the interest in scorpionfishes, our understanding of the systematic status of the species is poor for most areas of the world.

The present account deals with Atlantic species. Western Atlantic species which I have not treated earlier (Eschmeyer, 1965a, b; Eschmeyer and Collette, 1966; Eschmeyer and Bailey, in press) are studied in most detail, but all western Atlantic species are mentioned and are included in the keys (except North Atlantic species of the genus *Sebastes*). Pertinent additional material, references, or comments are given for some species treated in my earlier papers. Of the species occurring in the eastern Atlantic, those from the Gulf of Guinea are given most attention, based on collections by the Institute of Marine Sciences, the Guinean Trawling Survey, and the United States Fish and Wildlife Service. Other species from the eastern Atlantic, Mediterranean Sea, and islands of St.

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[1] Contribution no. 1068 from the Marine Laboratory, Institute of Marine Sciences, University of Miami, Florida.

Helena, Ascension, and Tristan de Cunha are included, except North Atlantic species of *Sebastes*.

Fifty-eight species in 11 genera are recognized; this includes one western Atlantic species of doubtful validity. Two species are treated as composed of two subspecies. In the eastern Atlantic the species occurring in the Mediterranean Sea and adjacent parts of the Atlantic deserve additional study, particularly in regard to distribution and early literature. The most comprehensive accounts of eastern Atlantic scorpionfishes are those by Norman (1935a), Fowler (1936), Cadenat (1945), and Boutiere (1958). Recently several species have been described as new from the eastern Atlantic: *Scorpaenodes arenai* Torchio 1962a, *Scorpaena gaillardae* Roux 1954 (= *S. stephanica*), and *Scorpaena folgori* Postel and Roux 1964 (here placed in *Neomerinthe*). Eschmeyer and Collette (1966) reported *Ectreposebastes imus* from the Gulf of Guinea and the western Atlantic. Wheeler and Eschmeyer (1968) removed *Helicolenus microphthalmus* from the Atlantic fauna. The supposed western Atlantic species *Scorpaena microlepis* Gunter was found (Eschmeyer and Bailey, in press) to have been described from a specimen of the eastern Pacific species *S. guttata* which had incorrect locality data. A new subgenus and three new species are described in the present paper.

The scorpionfishes found in the Atlantic Ocean belong to the more generalized subfamilies. Zoogeographically, several distributional patterns are evident. Comparison of species on both sides of the Atlantic shows that the deeper the species lives the greater the likelihood that it has a close relative on the opposite side of the Atlantic or occurs on both sides of the Atlantic. The genera containing shallow-water species show more endemism. In the genus *Sebastes* (broadly defined), the single species occurring in the extreme South Atlantic has affinities with the small South American Pacific fauna which in turn probably arose from ancestors which were able to move south along the tropical Central American coast; the presence of three species of *Sebastes* in the extreme North Atlantic is most easily explained by a trans-Artic origin. A few of the warm-water genera are so far known only from the Atlantic, but most are represented in the Indian and Pacific oceans. Some world-wide tropical and south-temperate genera are more speciose in the Atlantic than in other areas; in some cases this may be a result of more collection and study of the Atlantic fauna.

Species of the western Atlantic are given first within each genus, and in most cases the sections on comparisons in each species' account deal mainly with species of the same genus from the same side of the Atlantic. Major comparisons of the faunas and comments on zoogeography are given in a separate section. The key is divided into two parts, the first for western Atlantic species and the second for species occurring in the eastern Atlantic and islands of Saint Helena, Ascension, and Tristan da Cunha.

Acknowledgments

Specimens from the eastern Atlantic were obtained from several sources. Many came from the *Pillsbury* collections in the Gulf of Guinea. My participation in the two *Pillsbury* cruises off West Africa was supported by the University of Miami Deep-Sea Biological Program sponsored by the National Geographic Society. Operation of the *Pillsbury* was financed by a biological ship-time grant from the National Science Foundation. Additional specimens are from the Guinean Trawling Survey in the Gulf of Guinea (through Frank J. Williams), collections by Bruce B. Collette on Guinean Trawling Survey 1, and from collections by the United States Fish and Wildlife Service research vessel *Geronimo*; William J. Richards (Tropical Atlantic Biological Laboratory) provided some specimens collected by the R/V *Geronimo*. Julio Rodriguez-Roda (Instituto de Investigaciones Pesqueras, Cadiz, Spain) generously loaned specimens reported by Cervigon (1960) from Mauritania; Fernando Cervigon provided additional information. J. Blache (Institute Fundamental D'Afrique Noire, Gorée, Sénégal) loaned specimens of *Scorpaenodes africanus*. Edward C. Raney (Cornell University) loaned specimens collected by Gilbert Bane in the Gulf of Guinea. Donald P. de Sylva (Institute of Marine Sciences) provided color slides of two species from the Azores. A loan of specimens from the British Museum (Natural History) was through the generosity of Alwyne C. Wheeler and P. Humphrey Greenwood.

Specimens from the western Atlantic were from collections made by the United States Fish and Wildlife Service research vessel *Oregon*, sent by Harvey R. Bullis, Jr. Additional material was from collections by the Institute of Marine Sciences vessels *Gerda* and *Pillsbury*. Loans of additional specimens were from the United States National Museum, through Ernest A. Lachner, and from the Field Museum of Natural History, through Loren P. Woods and Miss Pearl M. Sonoda. Mrs. Myvanwy M. Dick, Museum of Comparative Zoology, Harvard University, loaned a specimen of *Scorpaena* collected at Bermuda.

I thank the following persons for help while examing specimens in their care: Ernest A. Lachner and staff (United States National Museum) and Bruce B. Collette (Ichthyological Laboratory, United States Fish and Wildlife Service, United States National Museum), P. Humphrey Greenwood and staff (British Museum [Natural History]), Frederick H. Berry and staff (Tropical Atlantic Biological Laboratory, Miami), James E. Böhlke and James C. Tyler (Academy of Natural Sciences of Philadelphia), Donn E. Rosen and James W. Atz (American Museum of Natural History), and J. Cadenat (formerly at Gorée, Sénégal).

Additional help came from various sources. James E. Böhlke (Academy of Natural Sciences of Philadelphia) provided information on species occurring in the Bahamas. Tomio Iwamoto (Institute of Marine Sciences) supplied color

slides of several species from *Oregon* stations. Jon C. Staiger (Institute of Marine Sciences) and Peter J. P. Whitehead (British Museum [Natural History]) examined the holotype of *Pontinus nematophthalmus* in the British Museum. Victor Sadowsky (Instituto Oceanografico, São Paulo) sent specimens of *Scorpaena plumieri* collected off southern Brazil.

I completed most of this study (in dissertation form) while associated with the Institute of Marine Sciences' program of oceanic fishes supported by the National Science Foundation (NSF grants 1350 and 4389), C. Richard Robins, principal investigator. I thank C. Richard Robins, committee chairman, for his guidance during the study. I am grateful to members of my dissertation committee, Frederick M. Bayer, Clarence P. Idyll, Donald R. Moore, and Edward S. Iversen, for their suggestions and comments.

Many of the students at the Institute of Marine Sciences aided in various ways, and I especially thank the following: Ray S. Birdsong, William P. Davis, Thomas Devany, David M. Dean, Alan R. Emery, Henry A. Feddern, Thomas H. Fraser, Tomio Iwamoto, Martin A. Roessler, David G. Smith, and Jon C. Staiger. Most of the photographs were taken by Henry Feddern. Donald Heuer provided some photographic equipment.

Revision of the text for publication was done while employed by the California Academy of Sciences. I thank the following persons for their help during this phase: Lillian J. Dempster, W. I. Follett, Warren C. Freihofer, Earl S. Herald, Edward L. Kessel, George S. Myers, and Pearl M. Sonoda. My wife, Lydia, provided encouragement and helped with typing, editing and proofreading.

Methods

Terminology of spines is shown in figure 1. In earlier papers (1965a, b; Eschmeyer and Collette, 1966) I followed Ginsburg (1953) in naming spines, but I have now changed some names to agree more closely with the terminology of other authors. Confusion exists in the literature concerning the names of some head spines; terminology used by several authors for some spines is shown below.

Present study	Ginsburg, 1953 Eschmeyer, 1965a, b Eschmeyer and Collette, 1966	Schultz, 1943 Smith, 1957a	Matsubara, 1943
interorbital	interorbital	coronal	(unnamed)
coronal	(unnamed)	postfrontal	coronal
tympanic	frontal	tympanic	tympanic
parietal	anterior parietal	parietal	parietal
nuchal	posterior parietal	nuchal	nuchal
supracleithral	supracleithral	humeral	supracleithral
upper and lower posttemporal	upper and lower posttemporal	posttemporal	posttemporal

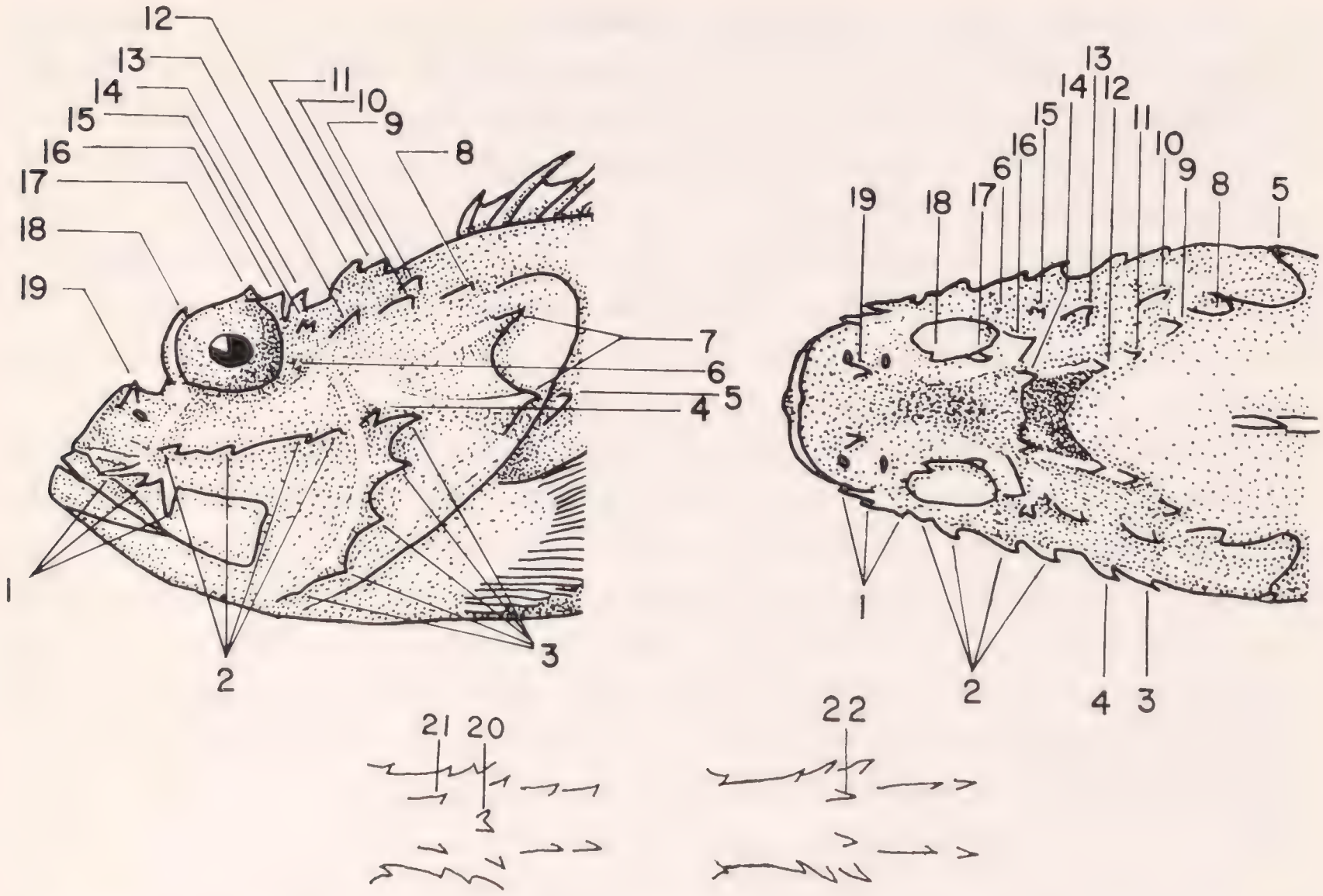


FIGURE 1. Diagram of head spines in scorpionfishes. (Numbers refer to names below.)

1. Preorbital
2. Suborbital
3. Preopercular
4. Supplemental preopercular
5. Cleithral
6. Fourth suborbital (postorbital)
7. Opercular
8. Supracleithral
9. Upper posttemporal
10. Lower posttemporal
11. Nuchal
12. Parietal
13. Pterotic
14. Tympanic
15. Sphenotic
16. Postocular
17. Supraocular
18. Preocular
19. Nasal
20. (unnamed)
21. Interorbital
22. Coronal

In Atlantic species the interorbital spines occur only in some species of *Scorpaenodes;* they do not seem to be identical to the coronal spines. The tympanic spines form the anterior corners of the occipital pit when present. These spines may be more lateral in species lacking a pit, and in some cases they are at the ends of long ridges which pass through the interorbital area; the tympanic spines are rarely absent. Some of the spines become blunt or almost imperceptible in larger specimens of some species; also the larger specimens of some species may have some spines variously split into numerous spinous points.

Measurements are as defined by Eschmeyer (1965a). Most are similar to measurements used to describe teleost fishes, with the following modifications: (1) Measurements originating at the snout are taken at the most anterior part of the left premaxillary because of the variable notch between the premaxillaries; (2) pectoral-fin length is measured from the base of the first ray to the apex of the fin, because the pectoral base is fleshy in some species and the ray bases difficult to distinguish. Some proportions change considerably with growth, particularly orbit diameter which tends to be proportionally smaller in larger specimens.

Several counts are useful in distinguishing species. The last two elements of the soft-dorsal and anal fins are counted as one. Gill-raker counts are usually given as total counts; distinction between rudiments and developed gill rakers is made in some cases. In some species the rudiments on the lower arch are difficult to count because of coalescence. The use of different methods for counting scales has caused confusion in the literature; some counts given as lateral-line scales refer rather to lateral scale rows. The tubed lateral-line scales are counted from the first one behind the supracleithral spine to the one over the posterior edge of the hypural; frequently one to three additional tubed scales are present on the caudal, and these are added with a plus sign. Vertical scale rows are counted above the lateral line from the row over the posterior end of the supracleithral spine to the row at the end of the hypural.

Abbreviations of depositories of specimens are as follows: AMNH—The American Museum of Natural History, New York, New York. ANSP—The Academy of Natural Sciences of Philadelphia, Philadelphia, Pennsylvania. BMNH—The British Museum (Natural History), London, England. CAS—California Academy of Sciences, San Francisco, California. FMNH—The Field Museum of Natural History, Chicago, Illinois. IFAN—Institute Français d'Afrique Noire, Gorée, Sénégal. IIP—Instituto de Investigaciones Pesqueras, Cadiz, Spain. TABL—Tropical Atlantic Biological Laboratory, Miami, Florida. UMML—University of Miami Marine Laboratory, Institute of Marine Sciences, Miami, Florida. USNM—United States National Museum, Washington, D. C.

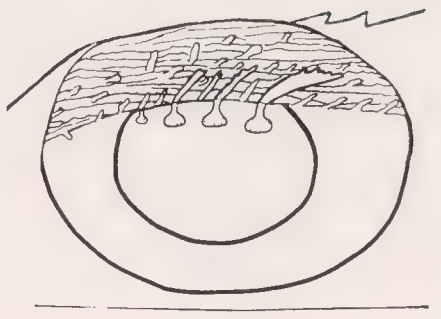
Key to Scorpionfishes of the Atlantic Ocean

The following key is divided for convenience into two parts, the first dealing with western Atlantic species and the second with species of the eastern Atlantic and islands of Saint Helena, Ascension, and Tristan da Cunha. Some characters useful in identification are shown in figure 2 and are referred to in the key. Specimens are depicted in figures 3–13.

A. Western Atlantic 1
B. Eastern and central Atlantic 30

a

b



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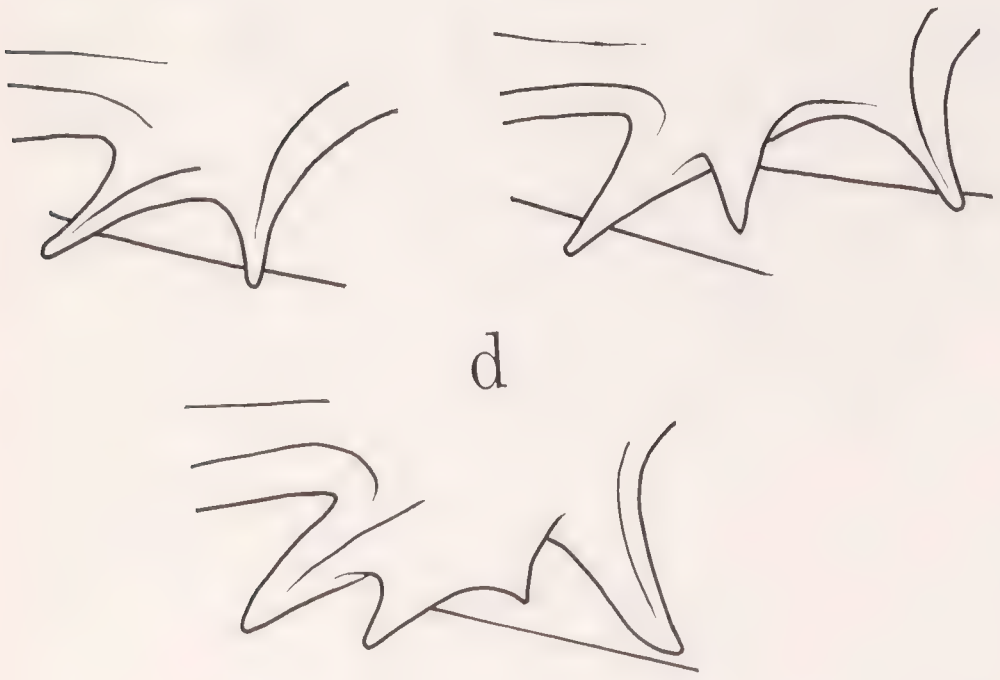

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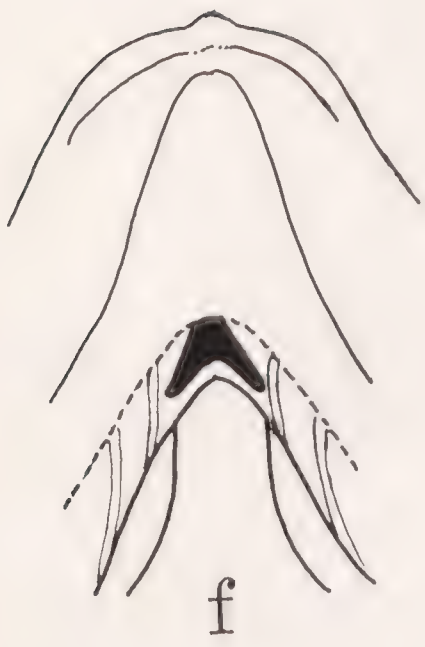
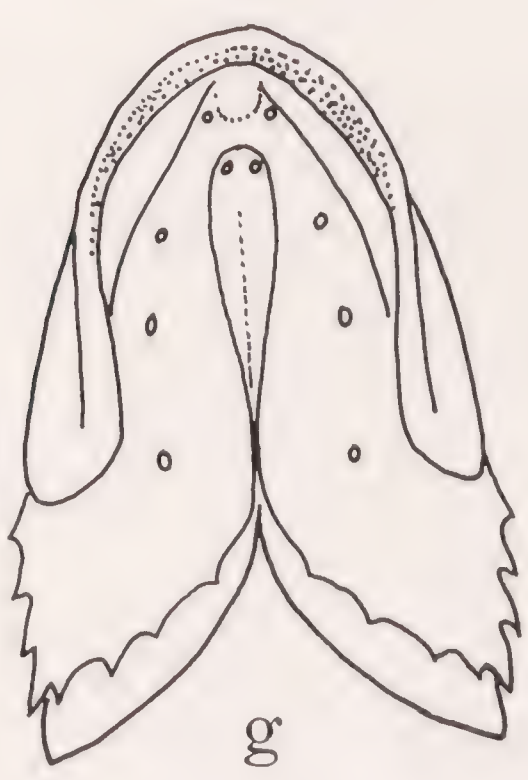
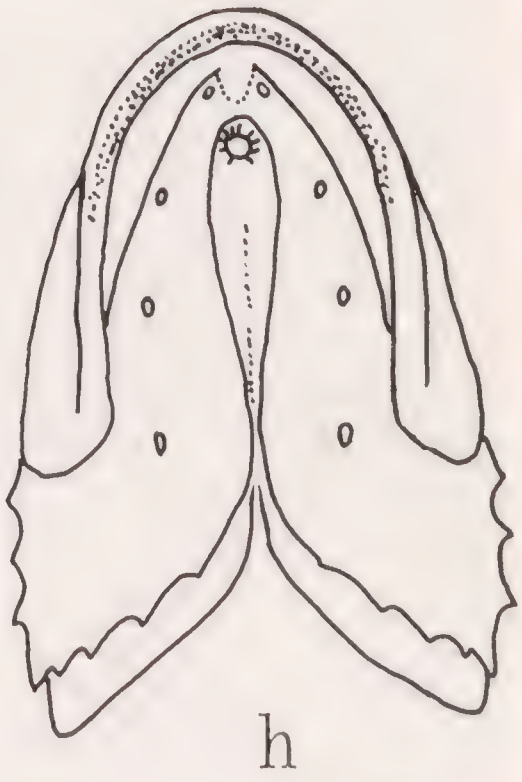


f



g



h

FIGURE 2. Characters useful in identification of Atlantic scorpionfishes. a. Additional row of spines on the suborbital bones in *Scorpaenodes caribbaeus*. b. Preopercular spines in *Helicolenus dactylopterus*. c. Mushroom-like tabs on cornea of *Scorpaena inermis*. d. Preorbital bones with 2, 3 and 4 spinous points. e. Maxillary with a median crest in *Scorpaena loppei*. f. Hypohyals (black) in *Pontinus nematophthalmus* (mouth open). g. Anterior mandibular pores separate. h. Anterior mandibular pores united. (g and h from Boutiere, 1958)

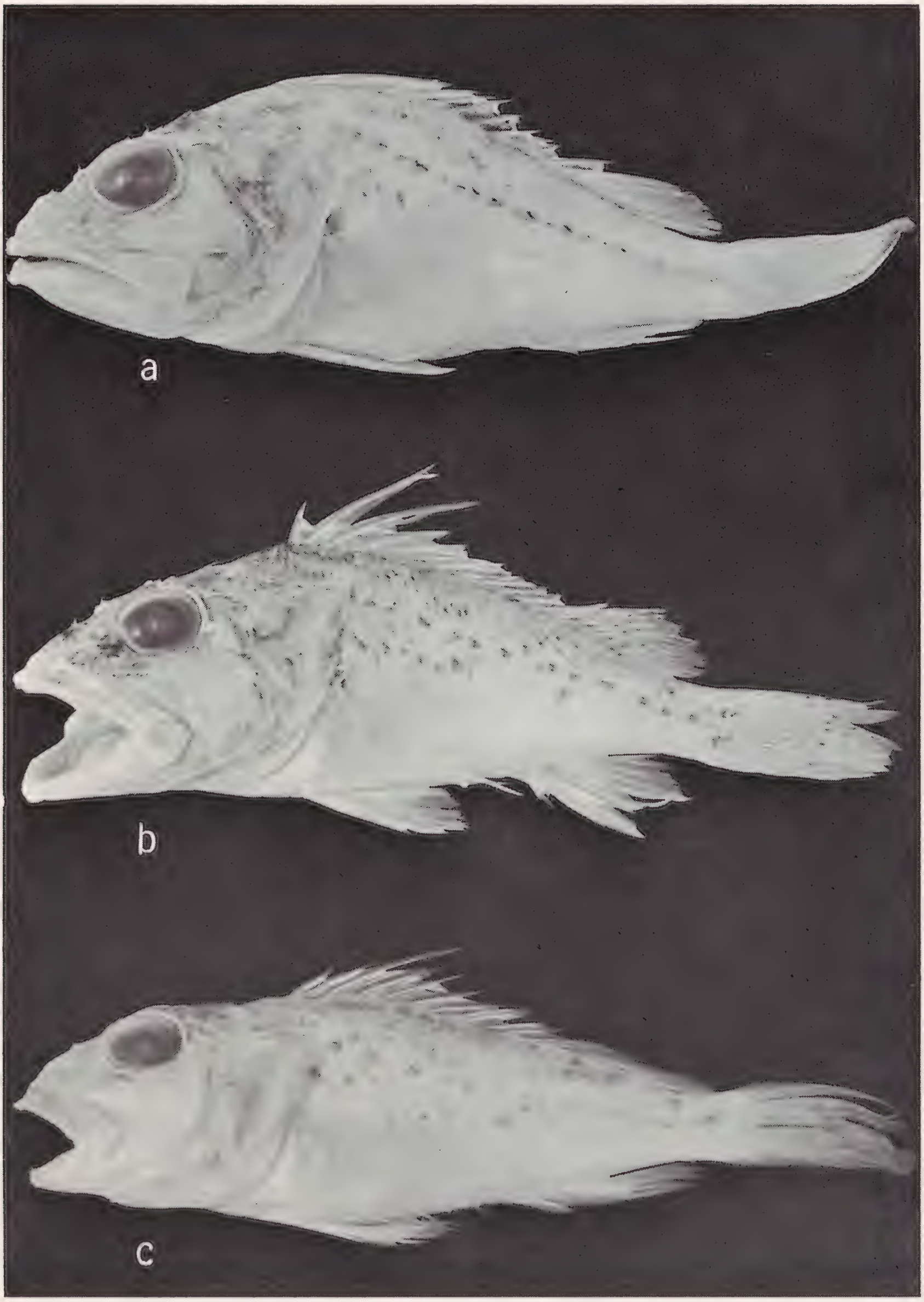


Figure 3. a. *Pontinus leda* (holotype), adult, 132 mm. S.L., CAS no. 24282, GERONIMO sta. 228, Gabon. b. *Pontinus accraensis*, adult, 158 mm. S.L., UMML 21770, Ivory Coast. c. *Pontinus longispinis*, adult, 162 mm. S.L., UMML 14017, Venezuela.

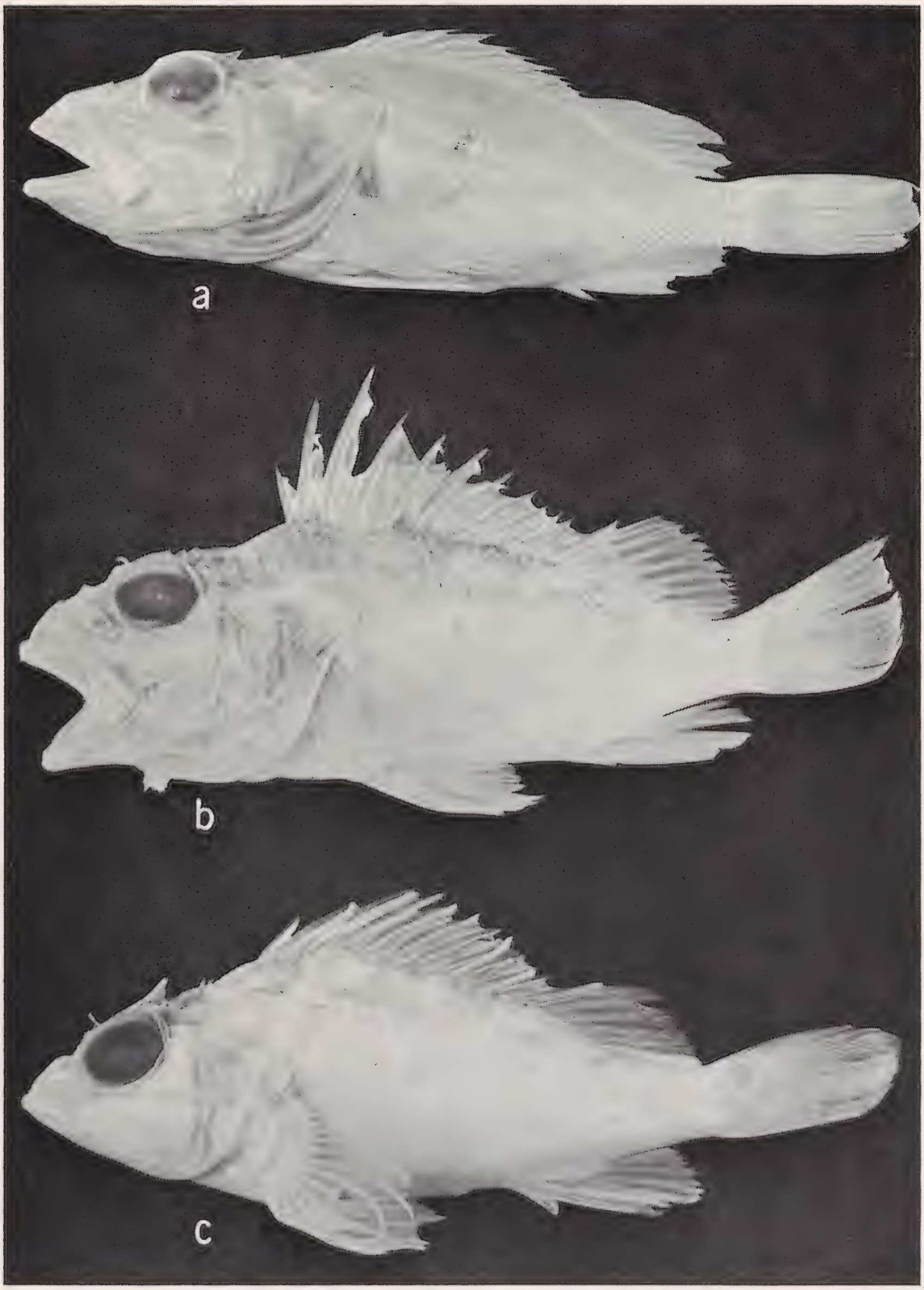


FIGURE 4. a. *Pontinus castor*, juvenile, 64 mm. S.L., UMML 14002, Haiti. b. *Pontinus nematophthalmus*, adult, 96 mm. S.L., UMML 14010, Venezuela. c. *Pontinus rathbuni*, adult, 72 mm. S.L., UMML 10359, Florida.

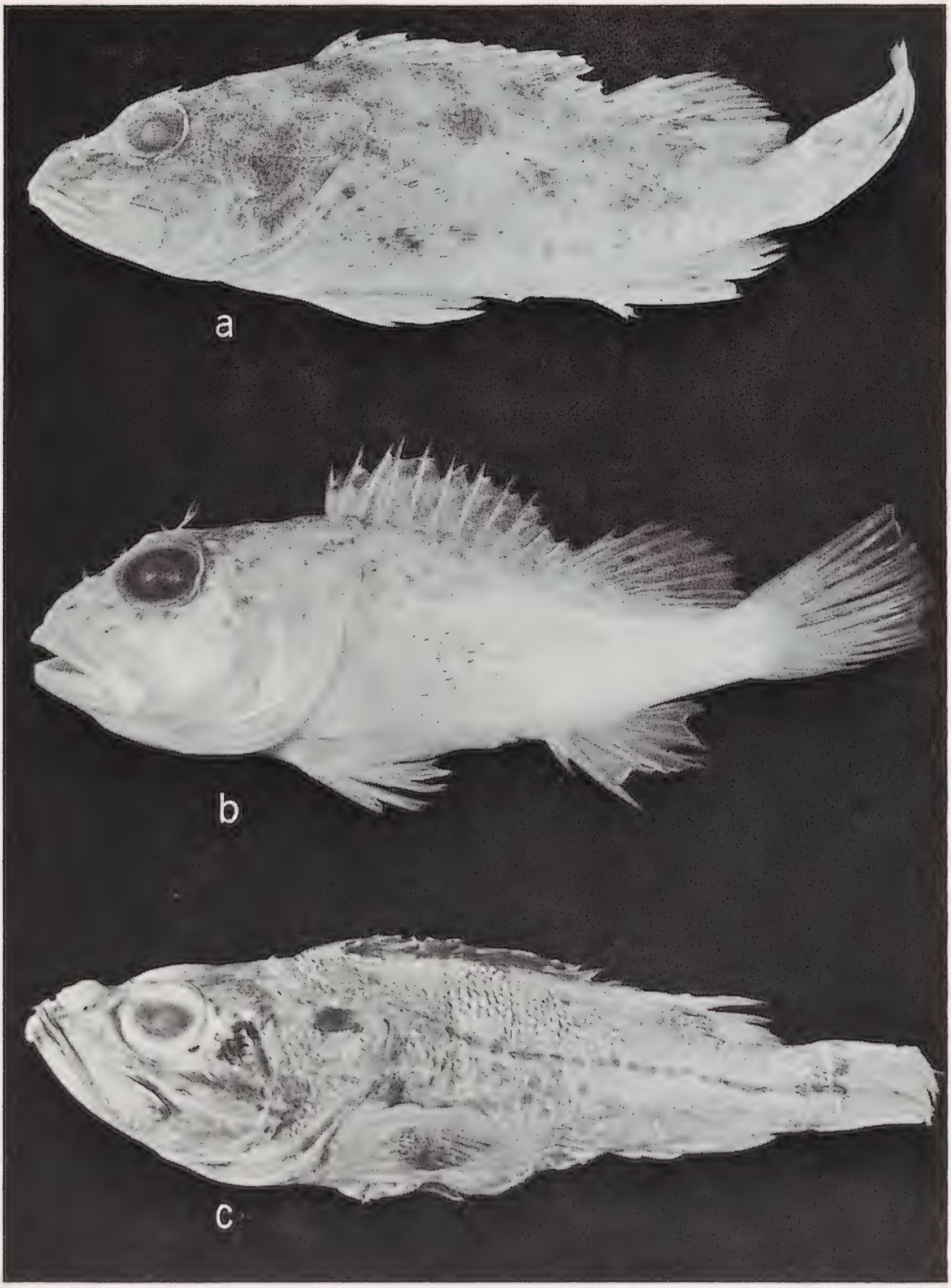


Figure 5. a. *Neomerinthe hemingwayi*, adult, 163 mm. S.L., UMML 14361, Georgia. b. *Neomerinthe beanorum*, adult, 69 mm. S.L., UMML 22171, Colombia. c. *Trachyscorpia capensis*, adult, 320 mm. S.L., BMNH.1935.5.2.10, Tristan da Cunha (caudal fin foreshortened).

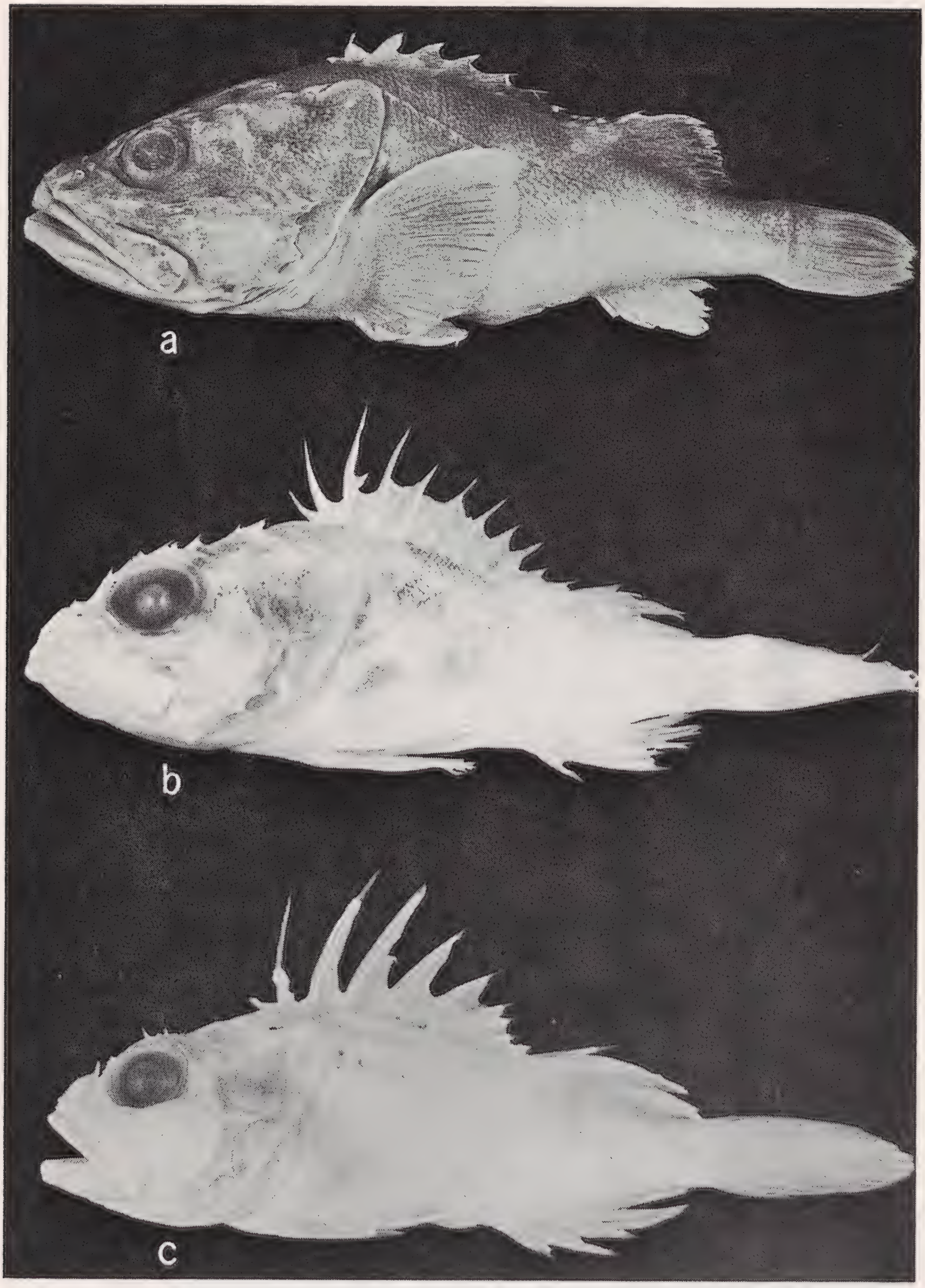


FIGURE 6. a. *Trachyscorpia cristulata cristulata*, large adult male, 345 mm. S.L., UMML 22223, Northern Gulf of Mexico. b. *Trachyscorpia cristulata cristulata*, juvenile, 75 mm. S.L., UMML 13732, Tortugas, Florida. c. *Scorpaena normani*, adult, 86 mm. S.L., UMML 21761, Nigeria.

Figure 7. a. *Scorpaena notata*, adult, 115 mm. S.L., USNM 48301, Bay of Naples. b. *Scorpaena notata*, subadult, 51 mm. S.L., UMML uncat., Spain. c. *Scorpaena loppei*, adult, 55 mm. S.L., USNM 201148, Bay of Naples.

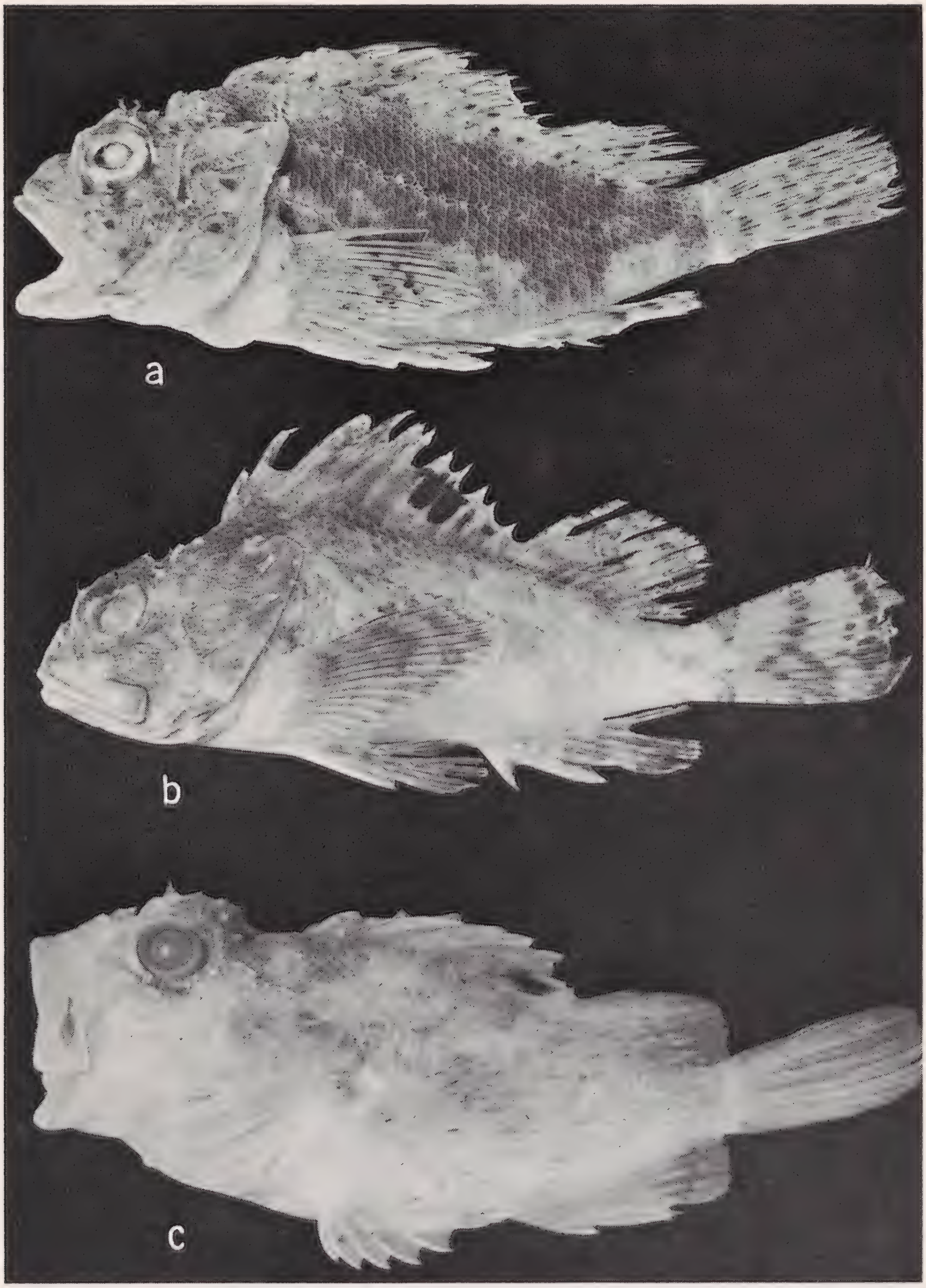


FIGURE 8. a. *Scorpaena azorica* (holotype), adult, 98 mm. S.L., USNM 94463, Azores. b. *Scorpaena angolensis*, adult, 91 mm. S.L., UMML 21772, Ghana. c. *Scorpaena annobonae* (holotype), adult, 44 mm. S.L., UMML 22219, Annobon.

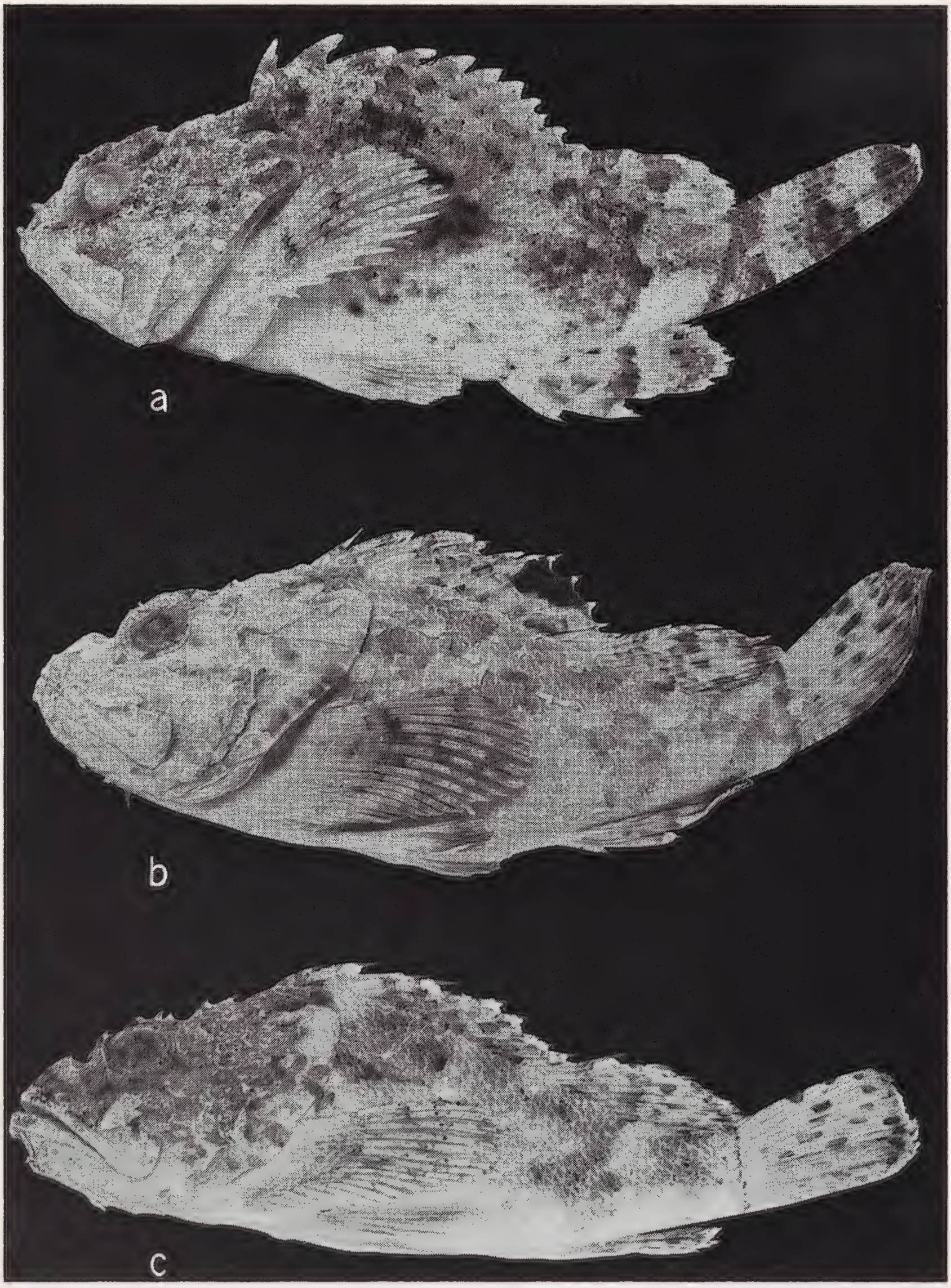


Figure 9. a. *Scorpaena porcus*, adult, 71 mm. S.L., UMML uncat., Spain. b. *Scorpaena scrofa*, adult (with dark spot on spinous dorsal fin), 135 mm. S.L., USNM 48302, Bay of Naples. c. *Scorpaena scrofa*, adult (lacking dark spot on spinous dorsal fin), 135 mm. S.L., USNM uncat., GTS Trans. 1, sta. 6, Portuguese Guinea.

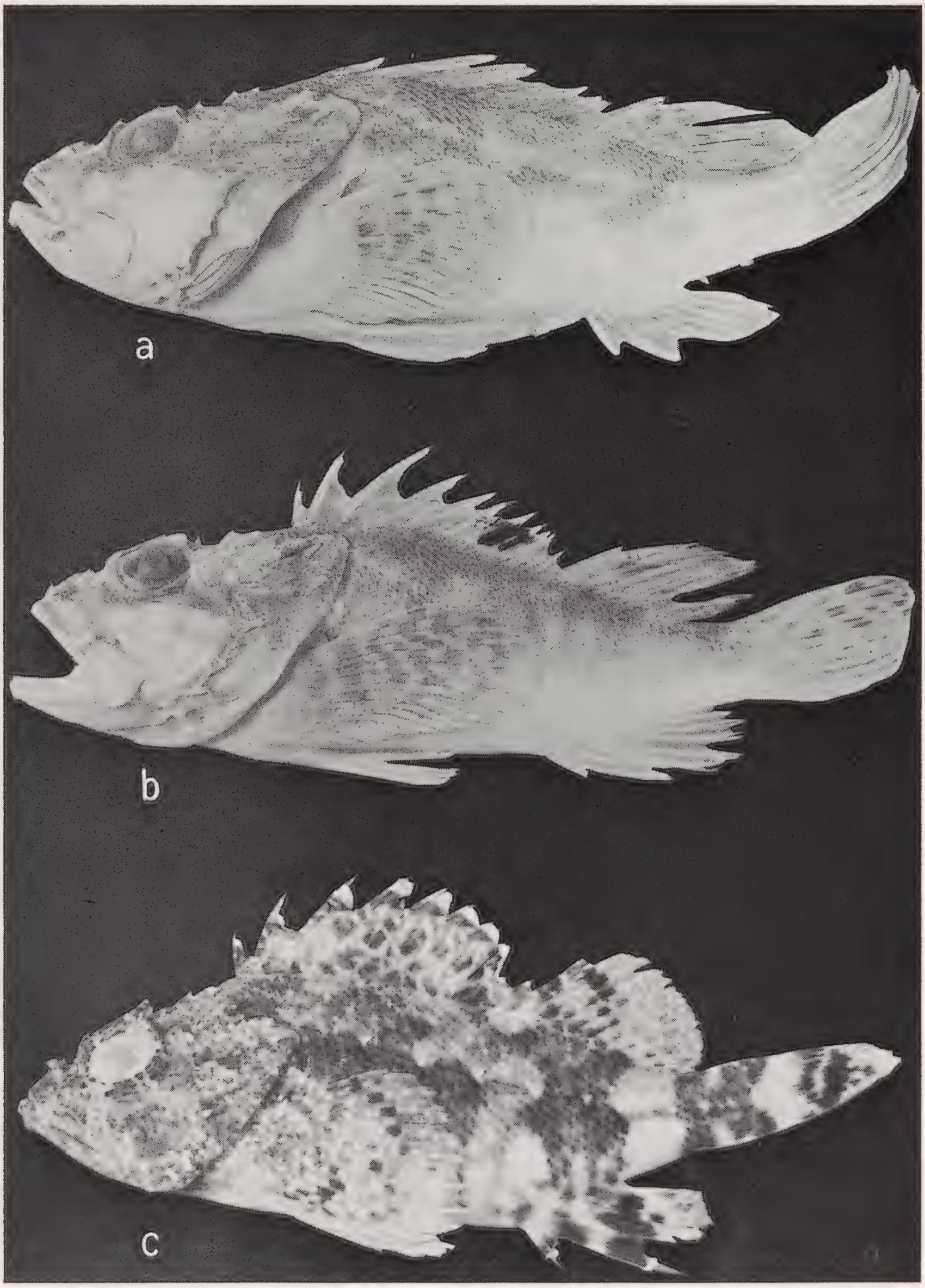


FIGURE 10. a. *Scorpaena elongata*, adult, 224 mm. S.L., UMML uncat., Portuguese Guinea. b. *Scorpaena stephanica*, adult, 148 mm. S.L., UMML 22873, Liberia. c. *Scorpaena maderensis*, juvenile, 41 mm. S.L., USNM 196334, Lebanon.

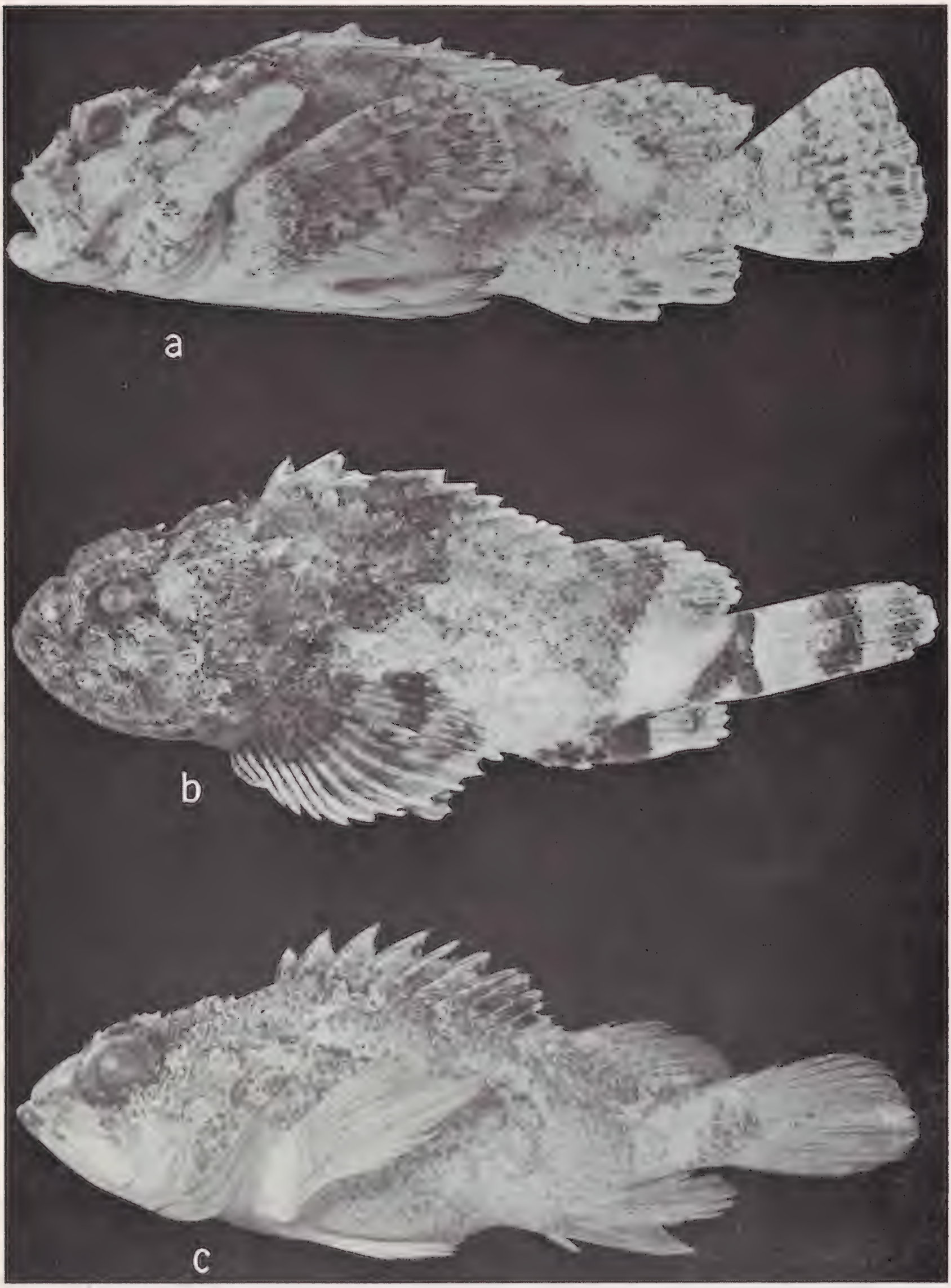


Figure 11. a. *Scorpaena laevis*, adult 200 mm. S.L., UMML 22217, Annobón. b. *Scorpaena laevis*, juvenile, 46 mm. S.L., UMML 22218, Annobón. c. *Scorpaenodes tredecimspinosus*, adult, 41 mm. S.L., UMML 19232, Florida.

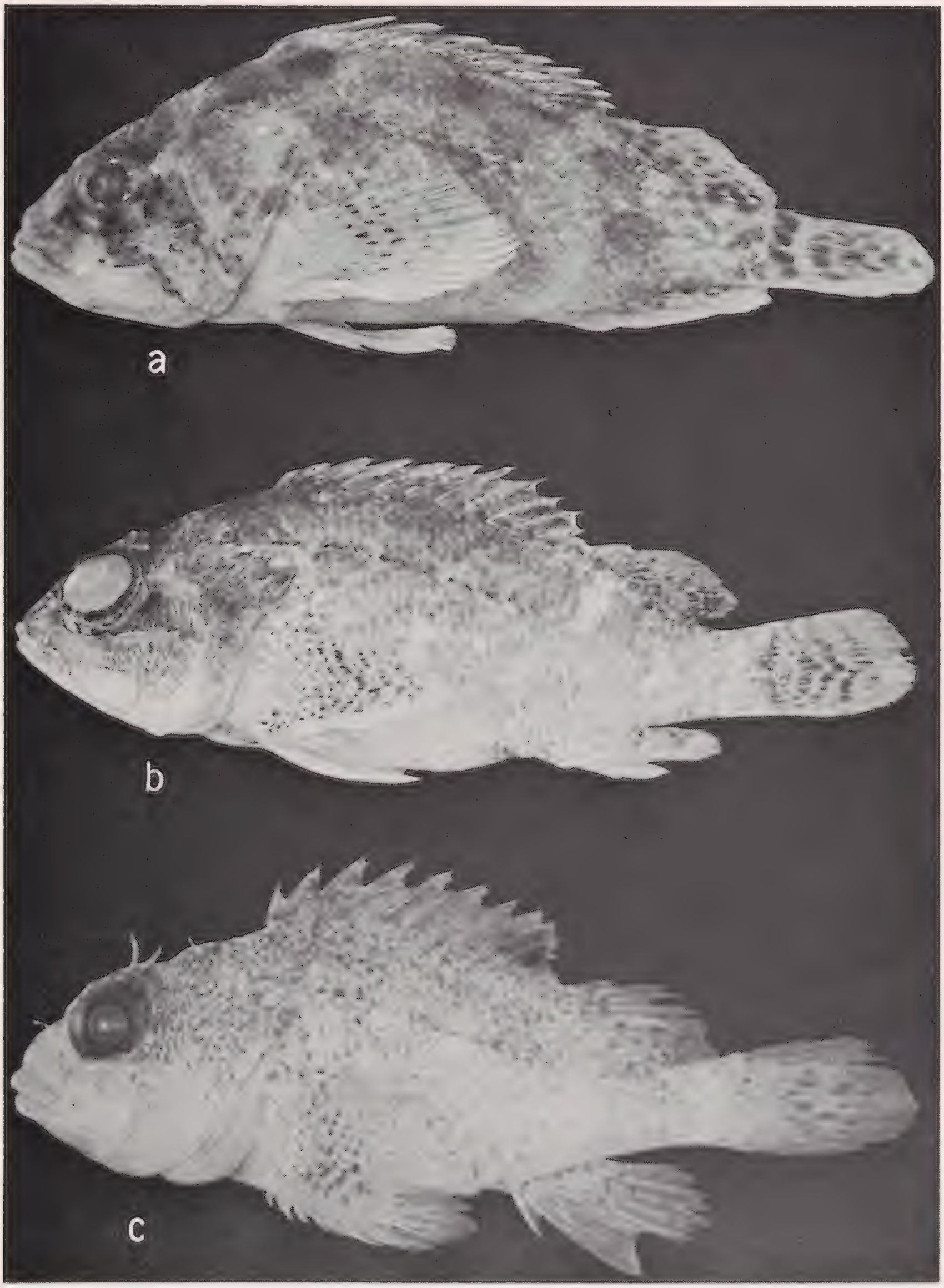


FIGURE 12. a. *Scorpaenodes caribbaeus*, adult, 74 mm. S.L., UMML 3740, Virgin Islands. b. *Scorpaenodes africanus*, adult 50 mm. S.L., Gorée 58–184, Gorée, Sénégal. c. *Scorpaenodes africanus*, adult, 33 mm. S.L., UMML 22220, Annobón.

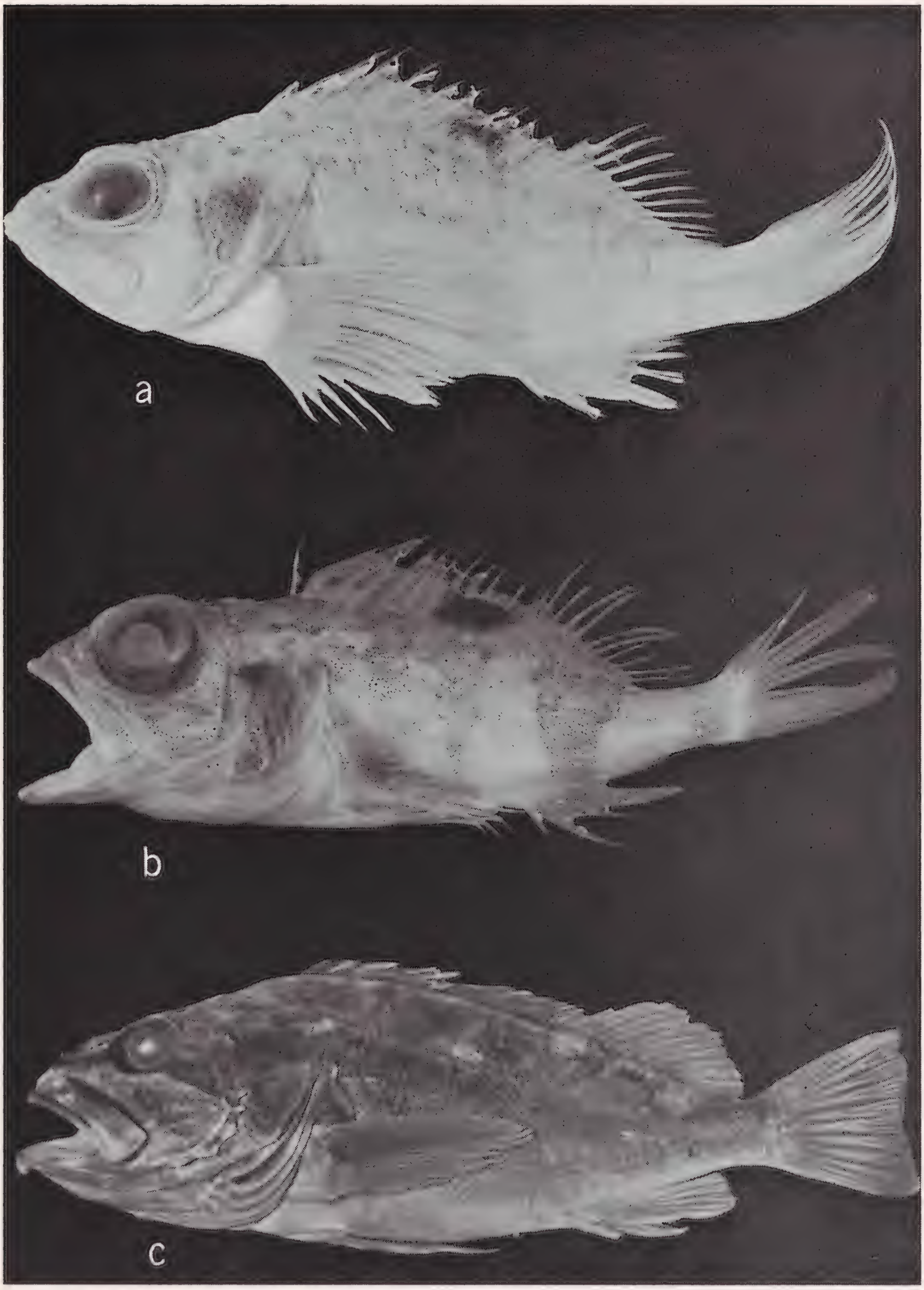


Figure 13. a. *Helicolenus dactylopterus dactylopterus*, small adult, 124 mm. S.L., UMML 12560, Florida Straits. b. *Helicolenus dactylopterus dactylopterus*, juvenile, 55 mm. S.L., UMML 21771, Ivory Coast. c. *Sebastes capensis*, adult, 280 mm. S.L., BMNH 1935.5.2.176, Tristan da Cunha.

WESTERN ATLANTIC

1. Dorsal spines 13 or more 2
1. Dorsal spines 12 (abnormal specimens with 13 dorsal spines will not possess the combination of characters of any triplet in 2) 4
2. (Trichotomous) Dorsal spines 14 or more; anal soft rays 7 or more (North-temperate to sub-Arctic) ..... *Sebastes* (species not treated in detail).
2. Dorsal spines 13; anal soft rays usually 6; palatine teeth present (South Atlantic); specimen figure 13c ..... *Sebastes capensis*
2. Dorsal spines usually 13; anal soft rays usually 5; palatine teeth absent (tropical to temperate) ..... *Scorpaenodes* 3
3. Pectoral rays 18–20, usually 19; one or more small spines just below main row of suborbital spines (fig. 2a); specimen figure 12a ..... *Scorpaenodes caribbaeus*
3. Pectoral rays 16–18, usually 17; suborbital ridge with a single row of spines; specimen figure 11c ..... *Scorpaenodes tredecimspinosus*
4. Lateral line of tubed scales; supraocular and postocular spines present; bones of head strongly ossified 5
4. Lateral line a continuous channel, roofed by thin scales; supraocular and postocular spines absent (except in juveniles); bones of head weakly ossified, cavernous 6
5. Second preopercular spine longest (fig. 2b); dorsal soft rays 11 or more (last double); specimen figure 13a, b ..... *Helicolenus dactylopterus*
5. First preopercular spine longest (as in fig. 1); dorsal soft rays 10 or fewer (last double) 7
6. Pectoral rays 18–20; anal soft rays usually 6; orbit diameter about 2 times into interorbital width ..... *Ectreposebastes imus*
6. Pectoral rays 21–24; anal soft rays usually 5; orbit diameter about equal to interorbital width ..... *Setarches guentheri*
7. Lateral line incomplete, only anterior 4–6 scales present ..... *Phenacoscorpius nebris*
7. Lateral line complete, extending to caudal base (sometimes some scales rubbed off) 8
8. Scales on body cycloid; (occipital pit present in all but 2 species) ..... *Scorpaena* 17
8. Scales on body ctenoid; (no occipital pit) 9
9. Pectoral fin not wedge-shaped, longest rays near upper edge (fin tends to be slightly bilobed in larger specimens); pectoral rays 21–24, rarely 20; specimen figure 6a, b ..... *Trachyscorpia cristulata cristulata*
9. Pectoral fin more or less wedge-shaped; pectoral rays usually 19 or fewer, rarely 20 10
10. All pectoral rays unbranched ..... *Pontinus* 11
10. At least some pectoral rays branched (except in juveniles) 15
11. Pectoral rays 19–20 ..... *Pontinus helena*
11. Pectoral rays 15–18 12
12. Snout long, orbit into snout 1.3–2 or more times; specimen figure 4a ..... *Pontinus castor*
12. Snout short, about equal to orbit diameter 13
13. Pectoral rays 16, rarely 15 or 17; ventral hypohyals with long descending arm (visible when mouth is open, see figs. 2f and 4b); specimen figure 4b ..... *Pontinus nematophthalmus*
13. Pectoral rays 17–18, rarely 16; ventral hypohyals without long descending arm ..... 14[2]

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[2] *Pontinus corallinus*, a nominal species known from southern Brazil and of uncertain validity, would probably key to couplet 14.

14. Third dorsal spine notably elongate in specimens greater than about 120–130 mm. standard length (*Neomerinthe beanorum* is the only other western Atlantic species with this character); first preorbital spine usually directed forward; sides of body usually spotted; specimen figure 3c ..... *Pontinus longispinis*
14. Third dorsal spine not notably elongate, sometimes slightly elongate in *P. nematophthalmus* as in figure 5b; first preorbital spine directed to rear; body with a few dusky smudges, especially in patches at base of dorsal fin; specimen figure 4c ..... *Pontinus rathbuni*
15. Dorsal soft rays usually 10, rarely 9 (last double); scales small, vertical scale rows more than 55; snout long, orbit into snout 1.1–1.7 times; specimen figure 5a ..... *Neomerinthe hemingwayi*
15. Dorsal soft rays 9 (rarely 8 or 10); vertical scale rows fewer than about 50; snout long, orbit into snout 0.7–1.3 times 16
16. Branched pectoral rays split once; body and most fins (especially the pectoral fins) usually with dark spots; 3 or 4 spines on suborbital ridge; (vertebrae 24); specimen figure 5b ..... *Neomerinthe beanorum*
16. Branched pectoral rays split more than once; body and fins mostly pallid; usually 5 or more spines on suborbital ridge; (vertebrae 25) ..... *Idiastion kyphos*
17. Preorbital bone with 2 spinous points over maxillary (fig. 2d) 18
17. Preorbital bone with 3 or 4 spinous points over maxillary (fig. 2d), except 2 in specimens of *Scorpaena plumieri* less than about 40 mm. standard length and probably 2 in specimens of *S. dispar* of the same length 29
18. Supplemental preopercular spine absent (refer to fig. 1); no occipital pit, except in *Scorpaena melasma* 19
18. Supplemental preopercular spine present; occipital pit present, sometimes shallow 21
19. Occiput broadly depressed, without a definite pit 20
19. Occiput with a deep pit ..... *Scorpaena melasma*
20. Inverted, mushroom-shaped, whitish (darker in preservative) figures extending down on cornea from base of ocular tabs at boundary of opaque and transparent parts of cornea (fig. 2c); dorsal soft rays usually 8 ..... *Scorpaena inermis*
20. Mushroom-shaped figures absent; dorsal soft rays usually 9 ..... *Scorpaena calcarata*
21. Brown spots (about 0.5–2 mm. in diameter) against pale background in axil of pectoral fin and along sides of body between pectoral and anal fin (sometimes faded); vertical scale rows more than 50 ..... *Scorpaena brasiliensis*
21. No brown spots in axil of pectoral fin; vertical scale rows usually fewer than 50 22
22. Eye large, snout 1.5–2.2 times in orbit; pectoral fin long, reaching to over posterior end of anal fin (shorter in juveniles) ..... *Scorpaena agassizii*
22. Eye moderate, snout 0.9–1.5 times in orbit; pectoral fin reaching to over third anal spine as maximum 23
23. Spinous dorsal fin with a dark blotch between dorsal spines 3–5 to 6–7 24
23. Spinous dorsal fin without a dark blotch 25
24. Pectoral rays 17 or 16; suborbital ridge with 1–3 spinous points ..... *Scorpaena bergii*
24. Pectoral rays 18–19, infrequently 17; suborbital ridge without spinous points ..... *Scorpaena isthmensis*
25. Axil of pectoral fin with white specks, less than about 0.5 mm. in diameter, surrounded by brown or on a tan background; supraocular tentacle long, usually two or more times orbit diameter; tympanic spines reduced or absent ..... *Scorpaena grandicornis*
25. Axil of pectoral fin not as above, usually axil pale; supraocular tentacle usually less than orbit diameter; tympanic spines present 26

26. Pectoral rays 16–18; suborbital ridge with 1 spine, infrequently 2 27
26. Pectoral rays 19–20; suborbital ridge usually with 3 spines, infrequently 2 28
27. Pectoral rays usually 18, sometimes 17; body depth 33–38 percent standard length (known only from Brazil) ..... *Scorpaena petricola*
27. Pectoral rays 17 or 16; body depth 37–42 percent standard length ..... *Scorpaena elachys*
28. Nasal spine usually absent; soft dorsal rays usually 8 ..... *Scorpaena brachyptera*
28. Nasal spine present; soft dorsal rays 9, rarely 8 ..... *Scorpaena albifimbria*
29. Axil of pectoral fin with large white spots or irregular blotches on a black background in specimens over about 30 mm. standard length (smaller specimens with a characteristic color pattern) ..... *Scorpaena plumieri*
29. Axil of pectoral fin unmarked; body pallid except for dark blotches, especially on pectoral fins and caudal fin ..... *Scorpaena dispar*

EASTERN AND CENTRAL ATLANTIC

30. Dorsal spines 13 or more 31
30. Dorsal spines normally 12 34
31. (Trichotomous) Palatine teeth absent; (shallow-water, tropical Africa and Mediterranean Sea) ..... *Scorpaenodes* 32
31. Palatine teeth present; second suborbital bone narrowing posteriorly; 1 or no spines on suborbital ridge ..... *Sebastes* (North Atlantic species not treated in detail; the one South Atlantic species, *S. capensis* (Gmelin) is treated.)
31. Palatine teeth present; second suborbital bone not narrowing posteriorly; several spines present on suborbital ridge (southern tip of South Africa); specimen figure 5c ..... *Trachyscorpia capensis*
32. Main row of spines on suborbitals with one or more spines below (fig. 2a) ..... *Scorpaenodes elongatus*
32. One row of spines on suborbitals 33
33. Suborbital ridge with 4 or more spinous points ..... *Scorpaenodes arenai*
33. Suborbital ridge with 3 or fewer spinous points; specimen figure 12b, c ..... *Scorpaenodes africanus*
34. Dorsal soft rays 11 or more (last double) 35
34. Dorsal soft rays 10 or fewer (last double) 37
35. Pectoral rays 19 or more; second preopercular spine longest (fig. 2b); suborbital ridge with 1 or no spines 36
35. Pectoral rays about 17; first preopercular spine longest (see fig. 1); suborbital ridge with several spinous points ..... *Neomerinthe folgori*
36. Body spotted with dark brown (Tristan da Cunha) ..... *Helicolenus tristanensis*
36. Body mostly pallid; specimen figure 13a, b ..... *Helicolenus dactylopterus*
37. Lateral line a continuous channel roofed by thin scales; supraocular and postocular spines absent (except in juveniles); bones of head weakly ossified; scales tiny and cycloid 38
37. Lateral line of tubed scales; supraocular and postocular spines present; ossification normal; scales on body ctenoid or if cycloid less than 80 vertical scale rows 39
38. Pectoral rays 18–20; anal fin with 6 soft rays (last double); orbit diameter about 2 times in interorbital width; top of head scaled ..... *Ectreposebastes imus*
38. Pectoral rays 21–24; anal fin normally with 5 soft rays; orbit diameter about equal to interorbital width; top of head naked ..... *Setarches guentheri*
39. Pectoral fin with characteristic shape (see fig. 6a), longest rays near upper part of fin; pectoral rays 20 or more ..... *Trachyscorpia cristulata echinata*
39. Pectoral fin wedge-shaped to rounded, longest rays at about middle of fin; pectoral rays usually fewer than 20 40

40. All pectoral rays unbranched; interorbital width 3.1–5.5 percent standard length; total gill rakers including flat rudiments 17–22 ..... *Pontinus* 41
40. Some pectoral rays branched, except in juveniles; interorbital width 4.1–9.0 percent standard length; total gill rakers including rudiments 13–18 ..... *Scorpaena* 44
41. Scales small, vertical scale rows more than about 60 ..... *Pontinus kuhlii*
41. Scales larger, vertical scale rows less than about 50 42
42. Occurring at Saint Helena ..... *Pontinus nigropunctatus*
42. Occurring off the west coast of Africa 43
43. Second anal spine long, about 1.5 (1.2–1.6) times orbit diameter; second and third dorsal spines usually notably elongate in specimens greater than about 130 to 150 mm. in standard length; caudal fin of preserved specimens spotted, especially along dorsal edge of fin (sometimes faded); pectoral rays usually 17 (16–18); specimen figure 3b ..... *Pontinus accraensis*
43. Second anal spine about equal to orbit diameter (orbit diameter 0.9–1.2 into length of second anal spine); no dorsal spines notably elongate; caudal fin of preserved specimens entirely clear, or dusky distally in large specimens; pectoral rays usually 18 (17–18); specimen figure 3a ..... *Pontinus leda*
44. Occipital pit absent 45
44. Occipital pit present 47
45. Chest naked; pectoral rays 18 or more; specimen figure 6c ..... *Scorpaena normani*
45. Chest scaled; pectoral rays 15–16, possibly 17 46
46. Both preorbital spines point to rear; 1 cleithral spine on each side; no white specks in axil of pectoral fin ..... *Scorpaena canariensis*
46. Only posterior preorbital spine points to rear; 2 cleithral spines on each side; white specks in axil of pectoral fin; specimen figure 10c ..... *Scorpaena maderensis*
47. Scales cycloid; pectoral-fin base and chest scaled 48
47. Scales ctenoid (or if emarginate (*S. porcus*), more than 60 vertical scale rows); pectoral-fin base and chest naked 49
48. Scale rows fewer than about 50; specimen figure 11a, b ..... *Scorpaena laevis*
48. Scale rows more than about 60 ..... *Scorpaena mellissii*
49. Anterior mandibular pores separate (fig. 2h) (sometimes difficult to locate) 53
49. Anterior mandibular pores united into a single opening (fig. 2g) (usually easy to locate) 50
50. Maxillary with a longitudinal crest (fig. 2e); specimen figure 7c ..... *Scorpaena loppei*
50. Maxillary lacking a crest 51
51. All fins with large brown spots; preorbital bone with 4 spinous points over maxillary (fig. 4d, lower) (probably only 2 or 3 in juveniles); specimen figure 8c ..... *Scorpaena azorica*
51. Spinous dorsal fin with an elongate black spot; preorbital bone with 1–3 spinous points over maxillary 52
52. Dorsal soft rays usually 9; preorbital bone with 3 spinous points over maxillary (fig. 2d, upper right), posterior one pointing slightly to rear; specimen figure 8b ..... *Scorpaena angolensis*
52. Dorsal soft rays 10 (1 specimen known); preorbital bone with 2 spines, first spine as broad shelf, second strongly curved to rear; specimen figure 8a ..... *Scorpaena annobonae*
53. Scales on body emarginate, vertical scale rows more than 60; specimen figure 9a ..... *Scorpaena porcus*
53. Scales on body ctenoid; vertical scale rows fewer than about 50 54

54. Cutaneous tabs present on underside of head; specimen figure 9b, c ..... *Scorpaena scrofa*
54. Lower jaw without cutaneous tabs 55
55. Spinous dorsal fin without a black spot; pectoral rays usually 19, sometimes 18; specimen figure 10a ..... *Scorpaena elongata*
55. Spinous dorsal fin with a black spot; pectoral rays usually 17–18, rarely 19 ..... 56[3]
56. Orbit diameter about equal to snout (small specimens) or smaller than snout, orbit into snout 0.8–1.2; scales before anus small, more than about 20 rows; specimen figure 10b ..... *Scorpaena stephanica*
56. Orbit larger than snout, ratio snout length divided by orbit diameter less than 0.9; scales before anus large, fewer than about 20 rows; specimen figure 7a, b ..... *Scorpaena notata*

Subfamily SCORPAENINAE

DIAGNOSIS. Dorsal normally XII–XIII; anal II–III, 3–6 (usually III, 5); pectoral rays normally 15–24; second suborbital bone uniformly broad or gradually becoming wider posteriorly, securely fastened to preopercle; suborbital sensory canal ending at posterior extremity of second suborbital bone; third suborbital bone usually absent; fourth usually present, isolated; vertebrae 24–26, mostly 24; lateral line of tubed scales.

REMARKS. This subfamily has been treated in detail by Matsubara (1943, p. 265, and following). The following genera not included by him are tentatively added: *Phenacoscorpius*, *Neomerinthe*, *Idiastion*, and *Trachyscorpia*.

Genus **Pontinus** Poey

Pontinus POEY, 1860, p. 172 (type-species *Pontinus castor* Poey [see Eschmeyer, 1965b, p. 527]). BARNHART AND HUBBS, 1946, pp. 373–377 (*Nemapontinus* and *Merinthe* as synonyms; comparisons). GINSBURG, 1953, pp. 42–44 (western Atlantic species). ESCHMEYER, 1965b, pp. 526–530 (nomenclatural problems; diagnosis; one new species added).

Sebastoplus GILL, 1863, p. 208 (type-species *Scorpaena kuhlii* Bowdich, by original designation).

Merinthe SNYDER, 1904, p. 535 (type-species *Sebastes macrocephalus* Sauvage, by original designation; no description). JORDAN AND EVERMANN, 1905, p. 461 (first description). MATSUBARA, 1943, pp. 286–287 (osteology of one species).

Nemapontinus FOWLER, 1938, p. 73 (type-species *Nemapontinus tentacularis* Fowler, by original designation; wrongly stated no palatine teeth).

Not *Pontinus*, MATSUBARA, 1943, pp. 282–283.

DIAGNOSIS. Dorsal rays XII, 9–10; anal rays normally III, 5; pectoral rays 15–20, all rays unbranched; swimbladder present; vertebrae 24; scales on body ctenoid; cheek, postorbital area and occiput scaly; no occipital pit; teeth on palatines; slit present behind last gill arch; peritoneum pallid.

SPINATION. Preorbital bone with 2 spinous points over maxillae. Suborbital ridge with 3 or 4 spinous points, first on preorbital frequently absent. Supplemental preopercular spine present; first preopercular spine longest,

[3] See Addendum.

second absent in some species (or absent in adults of some species), third present, fourth present, fifth small to virtually absent. Upper posttemporal spine absent in some species. Other spines include nasal, pre-, supra-, and postocular, tympanic, parietal, nuchal, pterotic, sphenotic, lower posttemporal, supracleithral, and cleithral. Some species with second and/or third dorsal spines greatly elongate in adults.

Remarks. This genus has been discussed recently (Eschmeyer, 1965b, pp. 526–528). About 15 valid species are recognized in the world-wide tropical genus *Pontinus*. In the Indo Pacific two species are valid: *P. macrocephalus* (Sauvage, 1882), including *P. spilistius* Gilbert, 1905 from Hawaii, and *P. tentacularis* (Fowler, 1938) from the Philippines and Japan. Barnhart and Hubbs (1946) correctly placed *P. spilistius* as a synonym of *P. macrocephalus* but also included *P. tentacularis*. The species occurring at Japan and the Philippines has been called *P. macrocephalus* by other authors (for example, Matsubara, 1943, as *Merinthe macrocephala;* Matsubara, 1955, as *Pontinus macrocephalus;* see Barnhart and Hubbs, p. 375); I (1965b) also thought that all might be synonymous. After examination of additional specimens (USNM and ANSP) I feel that two species are involved, one occurring at Hawaii and the other at the Philippines and Japan. The two species are distinguishable on number of pectoral rays and soft dorsal rays. *Pontinus tentacularis* has 16 pectoral rays and 9 soft dorsal rays (three specimens; Matsubara, 1943, gives pectoral rays as 16 (5) or 17 (1) and soft dorsal as 9 (5) or 10 (1). *Pontinus macrocephalus* has 17 pectoral rays and 10 soft dorsal rays (seven specimens). Other species of *Pontinus* show strong modes in these characters, therefore, *P. tentacularis* and *P. macrocephalus* are considered distinct, though closely related, species. *Sebastes hexanema* Günther (1880) from the Arafura Sea appears, however, to be a senior synonym of *P. tentacularis*, based on the figure given with the original description. Alwyne Wheeler informs me that the three types of *Sebastes hexanema* have 16 unbranched pectoral rays. Additional species are expected to occur in the Indo-Pacific area.

In the eastern Pacific there are six nominal species, at least five of which appear to be valid. Barnhart and Hubbs (1946, pp. 377–379) compared the five nominal species known then; *P. clemensi* Fitch was described in 1955.

Nine species are treated as occurring in the Atlantic Ocean. Three are found in the eastern Atlantic: *P. accraensis* Norman, 1935b, *P. kuhlii* (Bowdich, 1825), and *P. leda* Eschmeyer. Another species, *P. nigropunctatus* (Günther, 1868), occurs at Saint Helena. Five western Atlantic species are treated; *P. corallinus* Miranda Ribeiro from southern Brazil remains in doubt.

Characters most useful in separating species of this genus are numbers of pectoral rays and soft dorsal rays; presence of elongate dorsal spines and if elongate, whether the second, second and third, or third; scale size; direction of preorbital spines; and relation of size of orbit to length of snout. Two of these

must be used with caution: the dorsal spines usually do not become elongate until the fish reaches a size of 100 to 150 mm. standard length, and the ratio of snout divided by orbit changes radically with increases in size, those having the snout about twice as long as the orbit diameter in adults will have the two almost equal as juveniles. The length of the supraocular tentacle is of some use in distinguishing some species, but this character shows much variability, and the tentacles are frequently missing.

Pontinus helena Eschmeyer.

(See ESCHMEYER, 1965b, pp. 528–530, fig. 2, for a detailed treatment).

Pontinus helena ESCHMEYER, 1965b, pp. 528–530, fig. 2 (type locality Gulf de Triste, off Venezuela, 11°10′ N., 68°08′ W., in 220 fathoms, *Oregon* station 4451; holotype USNM no. 260470-F3, paratype UMML no. 16164).

DISTINGUISHING FEATURES. A short-snouted species with no elongate dorsal spines, characterized by a high pectoral fin ray count (19–20 rather than 18 or fewer).

DISTRIBUTION. Known only from the type material from off Venezuela in 220 fathoms.

Pontinus longispinis Goode and Bean.

Pontinus longispinis GOODE AND BEAN, 1896, p. 258, pl. 68, fig. 246 (type locality Gulf of Mexico, 28°36′ N., 85°33.5′ W., in 111 fathoms, *Albatross* station 2402; holotype USNM no. 39323). JORDAN AND EVERMANN, 1898, pp. 1858–1859 (compiled). EVERMANN AND KENDALL, 1900, p. 88 (compiled). JORDAN, EVERMANN, AND CLARK, 1930, p. 372 (compiled). HILDEBRAND *in* Longley and Hildebrand, 1941, p. 166 (description; color; Tortugas, Florida, in 60–140 fathoms). GINSBURG, 1953, pp. 45–47 (good description; 79 specimens from South Carolina south to Florida and in the Gulf of Mexico, in depths from 40–142 fathoms). SPRINGER AND BULLIS, 1956, p. 90 (collections by the *Oregon* in the Gulf of Mexico). BRIGGS, 1958, p. 294 (range compiled). BULLIS AND THOMPSON, 1965, p. 53 (collections by U. S. Fish and Wildlife Service exploratory fishing vessels). MOE, and others, 1966, p. 79 (specimens in Florida Board of Conservation collection). CERVIGON, 1966, pp. 768–770, fig. 325 (description; Venezuela).

MATERIAL EXAMINED. (For this species, station refers to *Oregon* stations and catalog numbers refer to UMML specimens unless otherwise noted.)

Northern population. ATLANTIC COAST OF FLORIDA: No. 1651 (1, 80) Duval County, off St. John's River entrance in 105 fathoms, vessel *Antillas*. NORTHERN GULF OF MEXICO: No. 16239 (59, 31–171) 29°42′ N., 86°45′ W., in 100 fathoms, station 4943; no. 16161 (2, 72–77) 29°21′ N., 87°40′ W., in 80 fathoms, station 4950; no. 14266 (36, 42–151) 29°13′ N., 88°11′ W., in 100 fathoms, station 4853; no. 16177 (1, 130) 28°59′ N., 88°37′ W., in 205 fathoms, station 4048; no. 16169 (2, 74–95) 29°13.5′ N., 88°12.5′ W., in 68 fathoms, station 2804; no. 16187 (6, 79–145) 28°11′ N., 90°08′ W., in 100 fathoms, station 4696; no. 16160 (1, 82) 28°16′ N., 90°13′ W., in 50–53 fathoms, station

4695; no. 17306 (4, 62–158) 27°55′ N., 91°43′ W., in 100 fathoms, station 4750; no. 17302 (2, 95–106) 28°40′ N., 92°21.5′ W., in 20 fathoms, station 4724 [depth must be wrong or station incorrect]; USNM no. 39323 (3, 54–122, holotype and 2 paratypes) 28°36′ N., 85°33′30″ W., in 111 fathoms, *Albatross* station 2402; USNM no. 39322 (1, 75, paratype) 28°38′30″ N., 85°52′30″ W., in 142 fathoms, *Albatross* station 2401.

Southern population (west to east). Panama: no. 22212 (1, 141) 9°02.3′–00.3′ N., 81°23.8′–25.0′ W., in 187–189 fathoms, *Pillsbury* station 445. Colombia: no. 16206 (1, 171) 10°24′ N., 75°50′ W., in 195–190 fathoms, station 4880; no. 16705 (1, 107) 11°06.7′N., 74°30′W., in 100 fathoms, station 4844; no. 17314 (5, 52–145) 11°09.5′ N., 74°24.5′ W., in 170–180 fathoms, station 4838; no. 16667 (1, 82) 11°08′ N., 74°23.8′ W., in 100 fathoms, station 4856; no. 16178 (2, 101–132) 11°50′ N., 73°05′ W., in 175–190 fathoms, station 4911. Venezuela: no. 14013 (2, 73–95) 11°53′ N., 69°28′ W., in 190 fathoms, station 4423; no. 16209 (4, 105–205) 11°49′ N., 69°24′ W., in 200 fathoms, station 4421; no. 14014 (1, 140) 11°50′ N., 69°23′ W., in 205 fathoms, station 4424; no. 16186 (3, 118–148) 11°11′ N., 68°11′ W., in 200 fathoms, station 4434; no. 16199 (3, 143–164) 11°10′ N., 68°08′ W., in 220 fathoms, station 4451; no. 14017 (5, 84–162) 10°54′ N., 68°01′ W., in 100 fathoms, station 4446; no. 16193 (9, 76–117) 10°45′ N., 66°37′ W., in 125 fathoms, station 4465; no. 16198 (4, 94–188) 11°30′ N., 60°46′ W., in 200–240 fathoms, station 5028. Surinam: No. 16179 (2, 105–108) 7°30′ N., 55°00′ W., in 100 fathoms, station 4304; no. 13323 (1, 111) 7°35′ N., 54°25′ W., in 150 fathoms, station 4302; no. 2033 (1, 68) 7°30′N., 54°16′W., in 125 fathoms, station 2013; USNM no. 185025 (2, 87–104) 7°34′ N., 54°50′ W., in 200 fathoms, station 2005. Brazil: USNM no. 185299 (1, 148) 2°04′ N., 47°00′ W., in 125 fathoms, station 2080.

Description. Counts and some measurements summarized in tables 1–9; body shape and coloration in figure 3c.

A short-snouted species with the third dorsal spine elongate in specimens over about 120 mm. standard length. Dorsal fin with 12 spines and 9 (rarely 8 or 10) soft rays. Pectoral rays 16–18, mostly 17 in northern population and 17 or 18 in southern population. Gill rakers 6–7 on upper arch, 8–10 on ceratobranchial, plus 3–6 often indistinct rudiments on hypobranchial. Preorbital bone with 2 spines over maxillary, anterior one usually points forward, second points back. Suborbital ridge usually with 4 points, first (on preorbital) sometimes absent. Second preopercular spine small, rarely absent; third preopercular spine points down or back, fifth spine usually sharp. Upper posttemporal spine small or absent. Other spines as for the genus. Vertebrae 24 (16 specimens). Vertical scale rows about 45–50. Supraocular tentacle small or absent, if present less than ½ orbit diameter. Orbit about equal to snout, ratio snout divided by orbit 0.8–1.1 (northern population), 0.7–1.3 (southern population), larger

specimens tend to have higher values; orbit into head 3.0–3.7, 2.9–4.1, larger specimens with higher values; interorbital width into orbit diameter 2.6–3.5, 2.7–3.4, larger specimens tend to have lower values.

Coloration as in figure 3c. Upper part of head and body, soft dorsal fin, and caudal fin with dusky spots or blotches on a pallid background. Frequently dusky pigment fades.

A species of moderate size, largest available 205 mm. in standard length.

GEOGRAPHIC VARIATION. Specimens from the two populations differ slightly in several counts and measuremnts. The southern population averages higher in pectoral-ray count (mean of 17.5 versus 17.0, table 2). The southern population averages a longer head (table 5), and correspondingly averages higher in jaw length (table 8), orbit diameter (table 3), and snout length (table 4). Other differences in modes appear to result mainly from the larger average size of the specimens measured from the southern population. The northern population also appears to average a longer second anal spine.

COMPARISONS. *Pontinus longispinis* is the only western Atlantic species of *Pontinus* with elongate dorsal spines (the third), but *P. nematophthalmus* and *P. rathbuni* sometimes have the third spine slightly elongate; this character is useful only for specimens over about 120 or 130 mm. in standard length, a size at which the third spine is notably elongate in *P. longispinis*. One other western Atlantic species, *Neomerinthe beanorum*, also has the third dorsal spine elongate, but it can be separated from *P. longispinis* by the presence of branched pectoral rays. The closest relative of *P. longispinis* is probably the eastern Pacific species *P. furcirhinus*, which also has the third dorsal spine elongate in larger specimens, anterior premaxillary teeth produced into prominent lobes, and a similar color pattern.

DISTRIBUTION. The northern population occurs from South Carolina, south around Florida to the northern Gulf of Mexico. The southern population occurs from Panama to Brazil. The species is considered a continental form. It is unknown from the Bahamas or the Antillian region, and is most abundant in the soft bottom areas south of Tortugas, off the Mississippi Delta, and off Colombia and Venezuela. Depths of capture range from 42 to 205 fathoms (one from 200–240).

Pontinus nematophthalmus (Günther).

Sebastes nematophthalmus GÜNTHER, 1860, p. 99 (western Atlantic specimen only; [lectotype designation by Ginsburg, 1953, p. 51; see Nomenclatural remarks]). NORMAN, 1935b, p. 22, footnote (types examined; suggested probably two species).

Pontinus pollux, DIAZ 1893, p. 87 (misidentified; color description; Cuba).

Pontinus macrolepis GOODE AND BEAN, 1896, pp. 257–258, pl. 69, fig. 247 (type locality off Cozumel, *Albatross* station 2354, 20°59′30″ N., 86°23′45″ W., in 130 fathoms). EVERMANN AND MARSH, 1900, p. 280, color pl. 43 (description; one specimen from off Puerto Rico, *Fish Hawk* station 6068, in 224–237 fathoms). JORDAN, EVERMANN, AND CLARK, 1930, p. 372 (compiled). GINSBURG, 1953, pp. 44–45 (good description; specimens from

off Cuba, Virgin Islands, and Puerto Rico, plus the type). Bullis and Thompson, 1965, p. 53 (collections by U. S. Fish and Wildlife Service exploratory fishing vessels).

Scorpaena nematophthalmus, Jordan and Evermann, 1898, p. 2861 (compiled from Günther).

Merinthe nematophthalma, Jordan, Evermann, and Clark, 1930, p. 372 (new combination; listed).

Pontinus castor, Ginsburg, 1953, p. 49, p. 51 (in part; designated Günther's western Atlantic specimen as lectotype of *P. nematophthalmus*; wrongly placed in synonymy of *P. castor* [see Nomenclatural remarks]).

Nomenclatural remarks. Norman (1935b) first pointed out that the two specimens in the original description of *P. nematophthalmus* (Günther) represented two species. One specimen was from the West Indies and the other from Ile de France? [Mauritius]. Barnhart and Hubbs (1946, p. 375) suggested that the specimen from the West Indies was obviously the type and was probably a synonym of *P. castor* (They incorrectly thought the other specimen was referable to *P. macrocephalus*). Ginsburg (1953, p. 51) designated the West Indian specimen as lectotype, and he placed *P. nematophthalmus* in the synonymy of *P. castor* on the basis of the long snout mentioned in the original description. On examination of the types, I (1965b, pp. 526–527) found the stuffed specimen from Ile de France? was the one with a long snout but that it was not a species of *Pontinus*. The specimen from the West Indies was a *Pontinus*, but a short-snouted specimen not referable to *P. castor*. At the time (1965b), I was unable to say which species of *Pontinus* Günther's species would replace. I failed to note the condition of the hypohyals, but Jon C. Staiger examined the lectotype for this character and found the long ventral processes well developed. This character, along with the pectoral-ray count of 16, leaves no doubt that *P. nematophthalmus* (Günther, 1860) is a senior synonym of *Pontinus macrolepis* Goode and Bean (1896).

Material examined. Florida: UMML no. 21777 (1, 60) 27°18′ N., 79°57′ W., in 47–53 fathoms, *Oregon* station 5301. Bahamas: UMML no. 17720 (1, 102) 25°55′–57′ N., 79°19′–18′ W., in 208 fathoms, *Gerda* station 626; UMML no. 13747 (1, 64) 27°00–01.5′ N., 79°15.5′–11.5′ W., in 130–150 fathoms, *Gerda* station 168. Cuba: USNM no. 100381 (1, 39) 23°10′30″ N., 82°20′25″ W., in 122 fathoms, *Albatross* station 2162. Virgin Islands: USNM no. 117789 (1, 102) 18°51′ N., 64°33′ W., *Caroline*. Puerto Rico: USNM no. 126131 (1) Mayaguez. Barbados: UMML no. 16157 (1, 68) 13°02′ N., 59°34′ W., in 110–135 fathoms, *Oregon* station 5015; UMML no. 16173 (7, 29–80) 13°04.5′ N., 59°39.5′ W., in 80–100 fathoms, *Oregon* station 5016. Yucatan (Caribbean): UMML no. 16264 (1, 89) 20°31′ N., 86°12′ W., in 150–164 fathoms, *Oregon* station 4938; UMML no. 16703 (1, 95) 20°25′ N., 86°13′ W., in 150 fathoms, *Oregon* station 4939. Honduras-Nicaragua: UMML no. 17308 (1, 53) 16°06′ N., 81°10.5′ W., in 90 fathoms, *Oregon* station 4932. Costa Rica: USNM no. 188199 (1, 76) 12°28′ N., 82°25′ W., in 100 fathoms, *Oregon* station 3578. Panama: USNM no. 188197 (3, 35–57)

12°32′ N., 82°25′ W., in 85 fathoms, *Oregon* station 3577. Venezuela: UMML no. 14012 (3, 34–53) 12°44′ N., 70°52′ W., in 55 fathoms, *Oregon* station 4397; UMML no. 14010 (13, 37–96) and UMML no. 14011 (1, 84) 12°37′ N., 71°10′ W., in 65 fathoms, *Oregon* station 4394; UMML no. 14009 (3, 69–78) 12°32′ N., 71°04′ W., in 46 fathoms, *Oregon* station 4393; UMML no. 14020 (1, 55) 10°15′ N., 66°55′ W., in 53 fathoms, *Oregon* station 4461; UMML no. 16172 (1, 93) 11°27′ N., 62°17′ W., in 65–70 fathoms, *Oregon* station 5040. Brazil: UMML no. 14005 (3, 40–67) 0°17′ N., 44°27′ W., in 60 fathoms, *Oregon* station 4224; USNM no. 185301 (17, 50–86) 2°40′ N., 47°56′ W., in 63 fathoms, *Oregon* station 2065.

Description. Counts and some measurements summarized in tables 1–9; body shape and coloration in figure 4b.

A small, short-snouted species with no especially elongate dorsal spines. Dorsal fin with 12 spines and 9 (rarely 8) soft rays. Pectoral rays 15–17, almost always 16. Gill rakers 6–7 on upper arch, 7–9 on lower arch, plus 2–5 often indistinct rudiments on lower arch. Preorbital bone with two spines over maxillary, both point back. Suborbital ridge with 3 or 4 spinous points, first on preorbital frequently absent. Second preopercular spine small (rarely absent) and nearer first than third, third and fourth point back or down, fifth blunt to absent. Upper posttemporal spine small to absent. Other spines as for the genus. Vertebrae 24 (12 specimens). Vertical scale rows about 42–47, usually some scales rubbed off. Supraocular tentacle often missing, but when present, usually long and slender, to twice orbit diameter. Orbit larger than snout in small specimens to about equal to snout in larger specimens, range of orbit into snout 0.7–1.1; orbit into head 2.9–3.8, larger specimens tend to have smaller values; interorbital width into orbit diameter 2.9–4.0.

Coloration as in figure 4b. Head and body usually with some dusky pigment; pigment on body usually more concentrated in poorly defined saddles, at beginning, middle, and end of spinous dorsal fin, and a fourth below the soft dorsal fin. Fins usually clear.

A small species, the largest specimen, the lectotype of *P. nematophthalmus*, measuring about 132 mm. standard length.

Comparisons. *Pontinus nematophthalmus* usually can be separated from other western Atlantic species on the basis of the pectoral-ray count of 16 (see table 2). The long processes from the ventral hypohyals (figs. 2f, 4b) are diagnostic for *P. nematophthalmus;* it is often necessary to depress the floor of the pharynx to reveal them, and they are frequently impossible to detect if the mouth is closed tightly. *Pontinus nematophthalmus* and *P. rathbuni* appear to be closely related; *P. nematophthalmus* seems to be a clear-water species and *P. rathbuni* a continental form unknown from insular areas. Besides the difference in the number of pectoral rays and the presence of prongs off the ventral hypohyals in *P. nematophthalmus*, the supraocular tentacle is usually

tapered and long in *P. nematophthalmus* and shorter and expanded at the tip in *P. rathbuni*, but the tentacle is often missing in both species.

Distribution. The species is known from Florida (one specimen), the Bahamas, throughout the Caribbean, and south to about the Amazon off Brazil. The species appears to be common about the islands of the eastern Caribbean. Depths of capture range from about 45 to 225 fathoms.

Pontinus castor Poey.

Pontinus castor Poey, 1860, p. 173 (type locality Cuba). Poey, 1861, p. 367 (listed). Poey, 1868, p. 303 (listed). Poey, 1875, p. 4 (listed). Diaz, 1893, p. 87 (Cuba; color; to 250 mm.). Jordan and Evermann, 1898, p. 1856 (compiled). Howell-Rivero, 1936, p. 62 (one specimen from off Havana Harbor). Ginsburg, 1953, pp. 49–51, fig. 5 (description; specimens from Cuba and Bermuda; wrongly included *P. nematophthalmus*). Briggs, 1958, p. 294 (compiled distribution; record from Gulf of Mexico probably in error [see Nomenclatural remarks]). Duarte-Bello, 1959, p. 124 (compiled). Bullis and Thompson, 1965, p. 54 (*Oregon* station 2607).

Pontinus pollux Poey, 1860, p. 174 (type locality off Havana, Cuba [see Nomenclatural remarks]). Poey, 1861, p. 367 (compiled). Poey, 1868, p. 303 (compiled). Poey, 1875, p. 4 (compiled). Jordan and Evermann, 1898, p. 1857 (compiled from Poey). Jordan, Evermann, and Clark, 1930, p. 372 (compiled). Howell-Rivero, 1936, p. 63 (two specimens from deep water off Havana, Cuba).

Scorpaena castor, Meek and Newland, 1885, pp. 397, 402 (questionably included *P. pollux* Poey; synonymy; description). Jordan, 1887, p. 596 (compiled).

Pontinus microlepis Bean, 1912, pp. 125–126 (type locality Bermuda; holotype USNM 74113).

Neomerinthe pollux, Ginsburg, 1953, pp. 53–56 (in part [see Nomenclatural remarks]). Duarte-Bello, 1959, p. 121 (compiled).

Nomenclatural remarks. Ginsburg, in his revision of western Atlantic scorpionfishes, placed *Pontinus pollux* Poey in the genus *Neomerinthe* as a senior synonym of *Neomerinthe hemingwayi* Fowler, but from available information this would appear incorrect and "*pollux*" is better treated as a junior synonym of *P. castor*. The type of "*pollux*" apparently is lost. Poey, in his description of "*pollux*", failed to note if the pectoral rays were branched; the presence of split pectoral rays is the main character separating species of *Neomerinthe* from *Pontinus*. Ginsburg (1953, p. 55) apparently did not consider the possibility that Poey had two specimens of *P. castor;* instead, Ginsburg suggested that since *N. hemingwayi* was very similar to *P. castor* and Poey stated that *P. pollux* was similar to *P. castor*, then *N. hemingwayi* was likely the same as *P. pollux*. Ginsburg (p. 55) noted certain discrepancies in this interpretation, for example, Poey's failure to mention a color pattern for *P. pollux*, and the fact that the width of the interorbital given by Poey for "*pollux*" was a little narrow if "*pollux*" were *N. hemingwayi*. Both of these discrepancies favor the view that Poey probably described "*pollux*" from a specimen of *P. castor*, since *N. hemingwayi* has a wider interorbital than *P. castor* (table 7) and *N. hemingwayi* usually has a definite color pattern while *P. castor* is usually pallid in the pre-

served state. Poey's description of "*pollux*" does not include other information of use in solving the problem. The differences in body shape, particularly the relation of snout length and orbit diameter, between a large and small specimen of *P. castor* would likely be greater than the differences in body shape of two similar-sized specimens of *N. hemingwayi* and *P. castor;* and with few specimens available, Poey could easily suspect two species were in hand.

Because Poey stated that his two species were similar in shape and both had 10 soft dorsal rays, Poey's "*pollux*" is less likely to be *P. nematophthalmus* (a short-snouted species with 9 soft dorsal rays), and the only other species of *Pontinus* which is now known from Cuba. The description as *P. pollux* by Diaz (1893) from Cuba is of *P. nematophthalmus*.

One record for *P. castor* from other than insular areas (Springer and Bullis, 1956) is treated as a misidentification (see account of *Neomerinthe hemingwayi*).

Material examined. Bahamas: UMML no. 14002 (3, 42–67) and TABL uncataloged (2, 62–68) south of Greater Inagua, 20°54′ N., 73°37′ W., in 75–100 fathoms, *Silver Bay* station 3502; UMML no. 17670 (1, 25) NW. Providence Channel, 26°04′ N., 79°13′ W., in 25–70 fathoms, *Gerda* station 636; TABL uncataloged (1, 66) 24°34′ N., 79°16′ W., in 150 fathoms, *Silver Bay* station 2471. Puerto Rico-Virgin Islands: USNM no. 187911 (1, 53) and USNM no. 187914 (1, 58) 18°35.5′ N., 64°57′ W., in 220 fathoms, *Oregon* station 2606 (corrected station list); FMNH no. 65864 (2, 52–64) 18°35′ N., 65°03′ W., in 42 fathoms, *Oregon* station 2607 (corrected list). Bermuda: FMNH no. 48526 (1, 256) 90 fathoms, L. L. Mowbray, 19 March 1940.

Description. Counts and measurements summarized in tables 1–9; body shape and coloration of a small specimen in figure 4a.

A long-snouted species with no especially elongate dorsal spines. Dorsal fin with 12 spines and 10 (9–11) soft rays. Pectoral rays 17 in available material. Gill rakers 5–8 on upper arch, 8–10 on ceratobranchial, and 2 to several flat rudiments on hypobranchial. Preorbital bone with 2 spines over maxillary, first blunt to almost imperceptable, second points out to slightly back. Suborbital ridge with 3 spinous points in available material (spines slight to virtually absent in largest specimens), none on preorbital. Second preopercular spine small in small specimens and usually absent in larger specimens; third and fourth spines usually point back; fifth points down and forward or virtually absent. Upper posttemporal spine small to absent. Nasal spine tiny, absent in largest specimen. Other spines as for the genus. Vertebrae 24 (six specimens). Vertical scale rows about 45–55. Supraocular tentacle when present small or elongate, about 2 or 3 times orbit diameter in some specimens, with dusky bands in two specimens. Orbit smaller than snout, ratio snout length divided by orbit diameter 1.0–1.3 in smaller specimens (as in fig. 4a) to 1.7 in largest specimen; orbit into head 3.5–5.2, larger specimens with higher values; interorbital width into orbit diameter 2.5–3.7, larger specimens tend to have lower values.

Preserved specimens generally pallid; some dusky pigment on sides of some specimens. In the smallest specimens there is usually some dusky pigment just before the end of the spinous dorsal fin.

A large species, the largest known about 260 mm. in standard length.

Comparisons. The long snout and dorsal soft-ray count of 10 characterize this species of *Pontinus*. The blunt or absent first preorbital spine also is characteristic. The species appears to be more closely related to species of other areas, for example, *P. macrocephalus* from Hawaii and *P. tentacularus* from the West Pacific, than to other Atlantic species in body shape, long snout, and no elongate dorsal spines.

Distribution. Records of *P. castor* are rare. Specimens are now known from Bermuda, Cuba, the Bahamas, and north of Puerto Rico and the Virgin Islands. The habitat is presumably rocky or rough bottom, and the species is probably widespread in the Antilles. Depths of capture range from about 40 to 220 fathoms.

Pontinus rathbuni Goode and Bean.

Pontinus rathbuni Goode and Bean, 1896, p. 255, pl. 68, fig. 245 (type locality off Cape Hatteras, North Carolina, 35°39′ N., 74°52′ W., in 80 fathoms, *Albatross* station 2298). Jordan and Evermann, 1898, pp. 1857–1858 (compiled). Jordan, Evermann, and Clark, 1930, p. 372 (compiled). Firth, 1931, p. 162 (North Carolina; brief description [AMNH no. 9693]). Nichols and Firth, 1936, p. 1 (compiled). Hildebrand, 1941, p. 228 (compiled). Fowler, 1952, p. 4 (off Key West in 90 fathoms, brief description). Ginsburg, 1953, pp. 47–49 (good description; specimens from Virginia south around Florida to Alabama). Springer and Bullis, 1956, p. 90 (listed; off Tortugas in 60 fathoms). Briggs, 1958, p. 294 (compiled range). Bullis and Thompson, 1965, p. 53 (collections by U. S. Fish and Wildlife Service exploratory fishing vessels). Moe, and others, 1966, p. 70 (specimens in Florida Board of Conservation collection).

Material examined. North Carolina: USNM no. 39325 (1, 116, holotype) 35°39′ N., 74°52′ W., in 80 fathoms, *Albatross* station 2298; USNM no. 190360 (3, 64–89) 34°04′ N., 76°15′ W., in 45–55 fathoms, *Silver Bay* station 1500; AMNH no. 9693 (1, 129) off Hatteras in 80 fathoms, F. E. Firth. Florida: UMML no. 2625 (4, 46–87) 28°52′ N., 80°05′ W., in 65 fathoms, *Combat* station 90; UMML no. 11092 (1, 65) 28°30′ N., 80°02′ W., in 37–41 fathoms, *Silver Bay* station 3704; UMML no. 10359 (3, 48–73) Monroe County, 5 miles ENE. of Alligator Reef Light, in 55 fathoms, CRR-F-324; UMML no. 17737 (1, 37) off Miami in 50 fathoms; UMML no. 12388 (2, 66–93) 24°29′–32′ N., 80°58′–54′ W., in 100–103 fathoms, *Gerda* station 133; UMML no. 12389 (2, 78–134) and UMML no. 13914 (1, 55) 24°32′–29′ N., 80°54′–53′ W., in 109–102 fathoms, *Gerda* station 134; UMML no. 13513 (9, 56–101) 24°34′ N., 83°28′ W., in 100 fathoms, *Oregon* station 4370; UMML no. 14004 (3, 56–87) 24°30′ N., 83°22′ W., in 100 fathoms, *Oregon* station 4143; UMML no. 16915 (2, 38–59) 24°30′–33′ N., 80°57′–54′ W., in 105 fathoms, *Gerda*

station 480; UMML no. 14288 (1, 69) 24°29′–30′ N., 80°53′–50′ W., in 120 fathoms, *Gerda* station 135; UMML no. 14356 (1, 64) 24°26′ N., 83°18′ W., in 100 fathoms, *Oregon* station 4556; UMML no. 21778 (1, 44) 25°10′ N., 80°06′ W., in 100 fathoms, *Gerda* station 763; ANSP no. 96646 (1) SE. of Sand Key Light in 90 fathoms, Thompson and McGinty. VENEZUELA: UMML no. 16211 (1, 197) 10°24′ N., 75°50′ W., in 190–195 fathoms, *Oregon* station 4880; UMML no. 15407 (1, 65) 12°09′ N., 72°47′ W., in 100 fathoms, *Oregon* station 4913; UMML no. 21775 (1, 128) 12°13′ N., 72°34′ W., in 100 fathoms, *Oregon* station 4920. SURINAM-FRENCH GUIANA: USNM no. 185024 (1, 90) 7°32′ N., 54°12′ W., in 100 fathoms, *Oregon* station 2014; USNM no. 185035 (1, 98) 7°18′ N., 53°32′ W., in 100 fathoms, *Oregon* station 2021.

DESCRIPTION. Counts and some measurements summarized in tables 1–9; body shape and coloration in figure 4c.

A short-snouted species with no especially elongate dorsal spines. Dorsal fin with 12 spines and 9 soft rays (see table 1 for abnormal specimens). Pectoral fin with 17 (rarely 16 or 18) rays. Gill rakers 6–7 on upper arch, 8–9 on lower arch followed by 3–5 low, often indistinct rudiments. Preorbital bone with 2 spines over maxillary, first points slightly to rear, second longer and curved to rear. Suborbital ridge usually with 4 spinous points, first on preorbital sometimes absent. Second preopercular spine moderate to small, usually nearer first than third; third usually points back, fourth down or slightly back, fifth small to absent. Upper posttemporal spine small to absent. Other spines as for the genus. Vertebrae 24 (three specimens). Vertical scale rows in middle forties, some scales usually rubbed off. Supraocular tentacle usually smaller than orbit, thick, sometimes split, and usually expanded at distal end. Orbit about equal to snout, slightly larger than snout in small specimens to slightly smaller than snout in larger specimens, range of orbit divided by snout 0.8–1.3; orbit into head 3.1–4.2, larger specimens with higher values; interorbital width into orbit diameter 2.6–3.9, larger specimens tend to have lower values.

Coloration as in figure 4c. Preserved specimens often faded; usually some dusky pigment retained in 4 saddle-shaped patches along back, first 3 under spinous dorsal fin and fourth under soft dorsal fin (similar to *P. nematophthalmus*). Dusky smudges infrequently retained on the pectoral fin, anal fin, and caudal fin (especially on the dorsal edge of the caudal fin), on some lateral-line scales, in pectoral-fin axil, on head, and at end of supraocular tentacle. A partially faded fresh specimen had orange (probably red in life) spots on the pectoral fin, soft dorsal fin, and caudal fin.

A species of moderate size, largest specimen available 197 mm. in standard length.

COMPARISONS. See accounts of *Pontinus longispinis* and *P. nematophthalmus*.

DISTRIBUTION. The species occurs from Virginia south around Florida,

in the northern Gulf of Mexico, off Venezuela, and the Guianas. Depths of capture range from about 40 to 200 fathoms.

Pontinus corallinus Miranda Ribeiro.

Pontinus corallinus Miranda Ribeiro, 1915, Scorpaenidae, pp. 4–5, pl. (type locality ESE. of Rasa, Brazil, in 100 meters, *Annie*, January 1903; three specimens, length of type 157 mm. total length; one specimen observed in market at Rio de Janeiro). Miranda Ribeiro, 1918, p. 165 (listed). Miranda Ribeiro, 1961a, p. 15 (two from 24°14′ S., 44°49′ W., and one from 25°18′ S., 47°10′ W.).

Remarks. The validity of this species remains in doubt. No specimens are available for study. The color pattern (spots of red, dorsal part of body with dark spots) is most like that of *P. longispinis*. The types of *P. corallinus* are of a size that would not have the third dorsal spine notably elongate. Miranda Ribeiro (1915) gives the gill rakers as 2+4 on the upper arch and 6+4 on the lower arch; if he counted the flat rudiments on the hypobranchial, *P. corallinus* would have about two fewer elements on the lower arch than other western Atlantic species of *Pontinus*, but he probably counted only developed rakers.

Pontinus accraensis Norman.

Pontinus accraensis Norman, 1935b, p. 23 (type locality Accra, Ghana). Irvine, 1947, p. 203 (brief description; Accra, Ghana). Cadenat, 1950, p. 241, fig. 177 (Sénégal; figure best fits *P. kuhlii*), p. 307 (listed). Cadenat, 1953, pp. 1088–1089, figs. 28, 29 (distinguished from *P. kuhlii*). Poll, 1959, pp. 177–182, fig. 65 (description; probably included specimens of *P. leda;* specimens from off SW. Africa between 0°00′ and 16°36′ S.). Sanchez, 1966, p. 155 (compiled; Angola).

Material examined. Gulf of Guinea: BMNH 1963.3.24.42 (1, 168, holotype) Accra, Ghana, collected by F. R. Irvine. The following were collected by the *Pillsbury*: UMML no. 16594 (4, 50–126) 4°37′ N., 2°32′ W., in 110 meters, station 32; UMML no. 21767 (6, 76–160) 4°57.5′ N., 5°22′ W., in 55–64 meters, station 59; UMML no. 21770 (65, 52–184) and UMML no. 15767 (3, 74–132) 5°05′ N., 4°04.5′ W., in 73–98 meters, station 65; UMML no. 16882 (1, 123) 4°59′ N., 9°37′ W., in 156–220 meters, station 83; UMML no. 16956 (1, 86) 4°57′ N., 9°30′ W., in 150–146 meters, station 82; UMML no. 21769 (14, 81–126, plus 1 cleared and stained) 3°49′ N., 7°38′ E., in 264–269 meters, station 255. The following 10 specimens were collected by the *Geronimo* in the southern Gulf of Guinea: CAS no. 24279 (4, 79–115) 2°01′ S., 8°50′ E., in 200 meters, station 203; CAS no. 24280 (1, 68) 2°30′ S., 8°58′ E., in 200 meters, station 212; CAS no. 24281 (5, 73–141) 4°00′ S., 10°35′ E., in 100 meters, station 235. Thirty-four additional specimens, 84–149 mm. S. L., collected by Bruce B. Collette on Guinean Trawling Survey 1, between 12°03′ N., 17°14′ W. to 4°32′ N., 8°21′ W., in 70–200 meters, have been deposited in the collection of the United States National Museum (USNM nos. 203785–203792). Additional specimens collected by the Guinean Trawling Survey

were identified and returned to IFAN, Gorée, Sénégal. MAURITANIA: IIP uncataloged (1, 170) Arguin Bank, coast of Mauritania.

DESCRIPTION. Measurements and counts summarized in tables 1–10; body shape and coloration in figure 3b.

A large-scaled, short-snouted species with one or usually two elongate dorsal spines in large specimens. Dorsal fin normally with 12 spines and 9 soft rays (last double). Pectoral rays 16–18, mostly 17; 6–7 gill rakers on upper arch, 7–9 on lower arch, followed by 3–5 often indistinct rudiments. Preorbital bone with 2 spines over maxillary, first points out, second curves back. Suborbital ridge usually with 4 spinous points, first on preorbital sometimes absent. Second preopercular spine present, third usually points back to slightly down, fourth down and back, and fifth down to slightly forward. Upper posttemporal spine small or absent. Other spines as for the genus. Vertical scale rows about 45–50. Supraocular tentacle small or absent, if present less than ½ orbit diameter. Orbit larger than snout in smaller specimens to slightly smaller than snout in larger specimens, ratio snout divided by orbit 0.7–1.2; orbit into head 2.9–4.3, larger specimens with higher values; interorbital width into orbit diameter 2.8–4.0, smaller specimens tend to have higher values.

Coloration usually as in figure 3b. Body and head with dusky spots, often darker spots on some lateral-line scales. Caudal fin usually spotted, especially along the dorsal edge. Soft dorsal fin usually spotted; anal fin sometimes with dark spots retained, especially at about midheight of fin and at bases of spines.

A moderate-sized species, largest available specimen 184 mm. in standard length.

COMPARISONS. *Pontinus accraensis* is similar to *P. leda* in general appearance. *Pontinus leda* has no especially elongate dorsal spines in adults, but this character is useful only for specimens over about 120 or 140 mm. standard length. These two species, which are compared under the account of *P. leda*, differ from *P. kuhlii*, the third eastern Atlantic species, in having larger scales (about 50 or fewer versus 60 or more), in some measurements, and in distribution.

DISTRIBUTION. *Pontinus accraensis* is known from the coast of Mauritania south to Angola. Depths of capture range from about 30 to about 150 fathoms; Poll's specimens from deeper depths possibly represent *P. leda*. Habitat is mud or sand bottom.

Pontinus kuhlii (Bowdich).

(A partial synonymy pertinent to the scope of the study. References without information in parentheses were not seen. Some references to this species are probably based on misidentifications or mixed collections.)

Scorpaena kuhlii BOWDICH, 1825, p. 123 (type locality Madeira).

Sebastes kuhlii, LOWE, 1841, p. 176. LOWE, 1843, pp. 115–119, pl. 16 (good description; color in life; 100–250 fathoms; Madeira). GÜNTHER, 1860, pp. 102–104 (brief description; skeleton; specimens from Canary Islands at Teneriffe, and Madeira). CAPELLO, 1867,

p. 255 (Lisboa and Setubal, Portugal; common name). Steindachner, 1867, pp. 69–71 (description; *S. filifer* in synonymy; specimens from Teneriffe, Canaries). Bean, 1879, p. 23 (specimens in USNM). Capello, 1881, p. 11. Vinciguerra, 1893, p. 312. ?Osorio, 1898, p. 196 (listed; São Tome). Seabra, 1911, p. 150. Nobre, 1935, p. 97 (compiled; Portugal).

Sebastes filifer Valenciennes, 1835, p. 21, pl. 2, fig. 2 (type locality Canary Islands). Capello, 1881, p. 11. Seabra, 1911, p. 150. Nobre, 1935, p. 97 (compiled; Portugal).

Sebastoplus kuhlii, Gill, 1863, p.208 (as type of new genus).

Sebastoplus filifer, Gill, 1863, pp. 208–209 (included in *Sebastoplus;* discussed discrepancies in original description of *Sebastes filifer*).

Sebastes filifera, Steindachner, 1865, p. 400 (listed; Santa Cruz and Teneriffe, Canary Islands; common name).

Sebastes (*Sebastichthys*) *bibroni* Sauvage, 1878, p. 116, pl. I, fig. 3 (type locality Sicily; figure of scale).

Sebastes (*Sebastichthys*) *filifer*, Sauvage, 1878, p. 118.

Sebastes kuhli, Günther, 1880, p. 3 (listed). Collett, 1896, p. 13 (Teneriffe, Canary Islands). Zugmayer, 1911, p. 110 (two specimens from *Princesse Alice* station 1202, 36°40′ N., 14°09′45″ W., in 264 meters).

Pontinus kuhlii, Goode and Bean, 1896, p. 253 (compiled description). Fowler, 1936, p. 928 (synonymy; description from Günther, 1860; one specimen in United States National Museum from Madeira). Cadenat, 1950, p. 241, fig. 177 (compared with *P. accraensis;* figure best fits *P. kuhlii*). Cadenat, 1953, p. 1088 (compared with *P. accraensis*). Collins, 1954, p. 31 (listed; Azores). Boutiere, 1958, p. 12, and following (coast of Morocco; life history notes). Poll, 1959, pp. 175–177, fig. 64 (description; good figure; one specimen from 8°30′ S., 12°58′30″ E., in 190–230 meters). Cervigon, 1960, p. 93 (coast of Mauritania). Blache, 1962, p. 74 (compiled). Sanchez, 1966, p. 154, fig. (compiled: Angola).

Pontinus bibronii, Goode and Bean, 1896, pp. 253–254 (compiled from Sauvage; thought to be synonym of *P. kuhlii*).

Pontinus filifer, Goode and Bean, 1896, pp. 254–255 (compiled description; close to *P. kuhlii*).

Pontinus kuhli, Roule, 1919, p. 60 (Cape Verde Islands and Bane Seine between Portugal and Madeira in 240 meters). Norman, 1935b, pp. 22–23 (synonymy; description; specimens in British Museum from 210–320 mm. total length; range compiled; *P. bibronii* may prove identical; brief description of *P. bibronii* from notes provided by Longley). Lozano Cabo, 1961, p. 147 (compiled). Lozano Cabo, 1963, p. 345 (listed; Spanish Sahara-Mauritania).

Material examined. Portugal: USNM no. 10194 (1, 146) from Vienna Museum. Mauritania: IIP uncataloged (1, 230) 20°36′ N. off coast of Mauritania, in 220 meters. Madeira: USNM no. 100717 (1, about 155). Azores: USNM no. 188404 (5, 157–230) San Miguel, Bruce B. Collette; USNM no. 23301 (1, 170) Fayal, McGuire.

Description. Measurements and counts summarized in tables 1–10.

A small-scaled, moderate-snouted species with the second and third (sometimes second or third) dorsal spines elongate in adults. Dorsal fin with 12 spines and normally 9 soft rays (last double). Pectoral rays usually 17 (infrequently 18, 16 also expected). Gill rakers on upper arch 7 (6–8), 9–10 on lower arch, followed by 4 (3–5) often indistinct rudiments, total 19–21. Preorbital bone

with 2 spines over maxillary, both point back. Suborbital ridge with 3 or 4 points, first on preorbital usually absent. Second preopercular spine small or absent; third and fourth usually point back. Upper posttemporal spine small. Other spines as for the genus. Vertical scale rows about 60–65. Supraocular tentacle small or absent, less than ½ orbit diameter if present. Orbit smaller than snout in available material (probably about equal to snout in smaller specimens), ratio snout divided by orbit 1.1–1.5; orbit into head 3.8–4.8, larger specimens with higher values; interorbital width into orbit diameter 2.3–2.8.

Coloration of preserved specimens pallid with dusky blotches along side. Soft dorsal fin usually spotted. Sides with blotches, dark pigment more concentrated at bases of dorsal spines. Spinous dorsal fin and anal fin sometimes with dusky blotches. Head with some dark pigment. Color in life as depicted on slides taken by Donald de Sylva of specimens from the Azores is as follows. General color reddish interspersed with yellow. Dusky pigment shows through red in areas described above as dusky in preserved specimens. Yellow especially on head, below suborbital ridge, behind orbit, and on opercle flap. Some yellow on body, more concentrated above pectoral-fin base and on flanks. Fins reddish, spots on soft dorsal, caudal, and pectoral fins. Iris reddish with yellow. A smaller specimen with more yellow; soft dorsal fin and pectoral fin mainly with yellow spots rather than reddish brown spots. Lowe (1843) reports similar coloration for specimens from Madeira and gives the inside of the mouth as white, with a large red patch above and behind near entrance of the gullet.

COMPARISONS. *Pontinus kuhlii* differs chiefly from *P. accraensis* and *P. leda* in having smaller scales. Like *P. accraensis* but unlike *P. leda* and *P. nigropunctatus* (St. Helena), *P. kuhlii* has the second and third dorsal spines elongate in large specimens. *Pontinus kuhlii* also differs in some measurements, especially orbit diameter and snout length. *Pontinus kuhlii* appears to live on hard bottom rather than the coastal mud and sand bottoms inhabited by *P. accraensis* and *P. leda*.

DISTRIBUTION. The species is known from Madeira, Cape Verde Islands, Canary Islands, Azores, Portugal, coast of Morocco and Mauritania, and from one specimen from the Mediterranean Sea (Sicily, type of *P. bibronii*). An old record is from São Tome. One additional record (Poll, 1959) is from off South Africa at 8°30′ S., 12°58′ W. [see Remarks]. The species was not collected by the vessels *Pillsbury* and *Geronimo*, or the Guinean Trawling Survey in the Gulf of Guinea. The species should prove more widely distributed in the Mediterranean Sea. It is abundant about islands and appears to inhabit hard-bottom areas. Boutiere (1958, p. 58) reported the capture of *P. kuhlii* on coral (rocky) bottom off Morocco. Depths of capture range from about 50 to 250 fathoms.

Remarks. The specimen collected by Poll off South Africa may represent a new species closely related to *P. kuhlii*. The counts and measurements given by Poll seem to agree with those of similar-sized specimens of *P. kuhlii*. In Poll's drawing only the third dorsal spine is shown as elongate; adult specimens of *P. kuhlii* usually have the second and third spines elongate. This feature is relatively constant in other species.

The record from São Tome (Osorio, 1898) is questionable, but occurrence about the islands of the Gulf of Guinea is not inconsistent with the hard-bottom preference shown by *P. kuhlii*.

Pontinus leda Eschmeyer, new species.

(It is probable that many of the specimens reported by Poll (1959, pp. 177–182) as *P. accraensis*, and particularly those from the deeper stations, belong to this new species. His figure is of *P. accraensis*. No other literature applies to this species.)

Material examined. All specimens were collected by the Bureau of Commercial Fisheries research vessel *Geronimo* on Cruise 2 in the southern Gulf of Guinea. holotype: CAS no. 24282, a specimen 132 mm. in standard length, 3°31′ S., 9°53′ E., in 400 meters, station 228. paratypes: CAS no. 24283 (1, 124) and CAS no. 24284 (1, 133, cleared and stained) taken with the holotype at station 228; USNM no. 204097 (4, 86–138) 1°56′ S., 8°47′ E., in 300 meters, station 204. additional material: CAS no. 24286 (7, 76–123) 4°31′ S., 10°53′ E., in 300 meters, station 246; CAS no. 24288 (1, 126) 4°03′ S., 10°22′ E., in 300 meters, station 237; CAS no. 24287 (4, 98–162) 3°02′ S., 9°21′ E., in 300 meters, station 220; CAS no. 24285 (4, 77–117) 2°31′ S., 8°51′ E., in 300 meters, station 213; USNM no. 204096 (2, 71–132) and, to be deposited at IFAN (2, 126–128) 1°00′ S., 8°29′ E., in 100 meters, station 189; TABL uncataloged (1, 163) 0°02′ S., 8°50′ E., in 295 meters, station 179.

A total of 28 specimens from 71 to 163 mm. in standard length, collected between 0°02′ S. and 4°03′ S., in depths from 100 to 400 meters.

Description. Measurements and counts summarized in tables 1–10; body shape and coloration in figure 3a.

A large-scaled, short-snouted species with no elongate dorsal spines in large specimens. Dorsal fin with 12 spines and 9 soft rays (one with 13 spines and 8 soft rays), the last double. Pectoral rays 17–18, mostly 18. Total gill rakers on outside of first arch difficult to count in larger specimens because of coalescence of rudiments on lower arch; developed rakers short; upper rudiments and rakers usually 6 (6–7), lower developed rakers usually 8–9 (7–9), rudiments when countable 3–5. Preorbital bone with 2 spines over maxillary, first points out, second out and back. Suborbital ridge usually with 4 spinous points, first on preorbital rarely absent (two specimens with 3 on one side, one with 5 on one

side). Preopercle with supplemental spine and 5 preopercular spines; second preopercular spine smaller than first or third, third usually points down, fourth and fifth down to slightly forward. Upper posttemporal spine small to absent. Other spines as for the genus. Vertebrae 24 (four specimens). Vertical scale rows 40–47. Tubed lateral-line scales 23–24, plus 1–2 on caudal fin. Supraocular tentacle small to absent, less than ½ orbit. Measurements in tables 3–9. Orbit larger than snout in most specimens to about equal to snout in largest specimens, ratio snout divided by orbit 0.7–1.0; orbit into head 3.1–3.8, larger specimens with higher values; interorbital width into orbit diameter 2.5–3.7.

Coloration usually as in figure 3a. Generally pallid with dusky smudges on body. Dark pigment on sides more concentrated at bases of dorsal spines and along lateral line. Spinous dorsal fin with dark pigment more concentrated at mid-height of membranes, more concentrated just before end of spinous dorsal fin, and appearing as a dark patch in most specimens. Soft dorsal fin clear or with a few dusky blotches or spots. Caudal fin clear in smaller specimens, distal end of fin sometimes dusky in larger specimens. Pelvic, anal, and pectoral fins clear. Color in life unknown.

Comparisons. *Pontinus leda* agrees with *P. nigropunctatus* (Saint Helena) and it differs from *P. kuhlii* and *P. accraensis* in having no elongate dorsal spines in large specimens. *Pontinus leda* has slightly larger scales than *P. kuhlii* and *P. nigropunctatus* (vertical scale rows 40–47 versus 50 or more). *Pontinus leda* is most similar to *P. accraensis*, the only species of *Pontinus* which overlaps it in distribution. The two can be distinguished on coloration, especially by the presence of dark spots on the caudal fin in *P. accraensis* (also in *P. nigropunctatus*), while the fin is clear or with the tip dusky in preserved specimens of *P. leda*. The second anal spine is longer in *P. accraensis* (1.2–1.6 times in orbit versus 0.9–1.2). Slight differences in averages of some measurements are shown in tables 3–9. The pectoral rays usually number 17 in *P. accraensis* and most frequently 18 in *P. leda*. Differences in measurements of *P. leda*, *P. kuhlii*, and *P. nigropunctatus* are in part due to the larger size of the specimens examined of *P. kuhlii* and *P. nigropunctatus*.

Distribution. Known from the material examined from off South Africa between 2°02′ S. and 4°03′ S. in depths from about 50–200 fathoms. Habitat is mud or sand bottom. The species was not taken by the vessel *Pillsbury* or the Guinean Trawling Survey in the Gulf of Guinea. The northern limit of distribution appears to be about the equator. As mentioned, many of the specimens reported as *P. accraensis* by Poll from off South Africa, especially those from his deeper and more southern stations, are possibly specimens of the new species.

Etymology. The name is from Greek mythology, Leda, mother of Clytemnestra, Castor, Helen, and Pollux.

Pontinus nigropunctatus (Günther).

Sebastes nigropunctatus Günther, 1868, pp. 225, 227–228 (type locality Saint Helena). Melliss, 1875, p. 105, pl. 20, fig. 1 (Saint Helena; common name deep-water jack; caught throughout the year in 80–100 fathoms).

Pontinus nigropunctatus, Norman, 1935b, p. 22 (distinguished from *P. kuhlii* and *P. accraensis*). Fowler, 1936, p. 929 (compiled from Günther). Cadenat and Marchal, 1963, p. 1305 (listed).

Material examined. BMNH 1867.10.8.4–5 (2, 193–272, types) Saint Helena, collected by Melliss.

Description. Measurements and counts summarized in tables 1–10.

A large species with moderate snout, moderate-sized scales, and no elongate dorsal spines. Dorsal fin with 12 spines and 9 soft rays (last double). Pectoral fin with 18 rays. Gill rakers on upper arch 6–7, 12 on lower arch including rudiments. Preorbital bone with 2 spinous points over maxillary, posterior spine multiple in largest specimen. Suborbital ridge with 4 spinous points. Second preopercular spine small, nearer first than to third. Upper posttemporal spine small. Other spines as for the genus. Vertical scale rows 51–52. Orbit smaller than snout in available material, but probably about equal to snout or larger than snout in small specimens, ratio snout divided by orbit 1.3–1.7; orbit into head 4.3–4.9 (smaller specimens probably will have lower values); interorbital width into orbit diameter 2.0–2.3.

Specimens partially faded; a few dusky specks present on body, soft dorsal fin and anal fin. Günther gives the color as reddish-rose, with numerous brownish-black dots and white scattered specks between.

Comparisons. *Pontinus nigropunctatus* agrees with *P. leda*, but differs from *P. accraensis* and *P. kuhlii*, in having no elongate dorsal spines in adults. *Pontinus nigropunctatus* differs from the other species in coloration.

Distribution. Known from the two type specimens from Saint Helena.

Genus **Neomerinthe** Fowler

Neomerinthe Fowler, 1935, p. 41 (type-species *Neomerinthe hemingwayi* Fowler, by original designation). Ginsburg, 1953, pp. 51–53 (description; western Atlantic species).

Diagnosis. Dorsal rays XII, 8–11; anal rays III, 5; pectoral rays 16–18; some rays branched; swimbladder present; vertebrae 24; scales on body ctenoid; cheek, postorbital area, and occiput scaled; no occipital pit; teeth on palatines; slit present behind fourth gill arch; peritoneum pallid.

Spination. Preorbital bone with 2 spinous points over maxillary, sometimes each subdivided into several spinous points. Suborbital ridge with 3 to many points. Supplemental preopercular spine present; first preopercular spine longest, second small to absent, third and fourth present, fifth present to virtually absent. Upper posttemporal spine small to absent. Other spines present include nasal, pre-, supra-, and postocular, tympanic, parietal, nuchal, pterotic, sphenotic

(usually as group of small spines), lower posttemporal, supracleithral, and cleithral. One species with the third dorsal spine elongate in adults.

REMARKS. The genus *Neomerinthe* is very close to *Pontinus*, differing in having some branched pectoral rays. The branching is simple, rather than compound as found in adults of most species of the subfamily. The genus *Neomerinthe* is restricted to the Atlantic, with two species in the western Atlantic, and one species from the eastern Atlantic tentatively assigned to it.

Neomerinthe hemingwayi Fowler.

Neomerinthe hemingwayi FOWLER, 1935, p. 41, fig. (type locality 70 miles southeast of Cape May, New Jersey; holotype ANSP no. 63482).

Neomerinthe tortugae HILDEBRAND *in* Longley & Hildebrand, 1940, p. 247, fig. 13 (type locality Tortugas, Florida; holotype USNM no. 108871, 2 paratypes USNM no. 108872). LONGLEY AND HILDEBRAND, 1941, p. 166 (listed).

Pontinus castor, SPRINGER AND BULLIS, 1956, p. 90 (misidentified [see Nomenclatural remarks]; Gulf of Mexico; listed).

Neomerinthe pollux, GINSBURG, 1953, pp. 53–56 (incorrectly treated *P. pollux* Poey as senior synonym of *Neomerinthe hemingwayi* [see Nomenclatural remarks]; synonymy; good description; specimens from New Jersey south to Florida and in the northern Gulf of Mexico). SPRINGER AND BULLIS, 1956, p. 90 (captures by vessel *Oregon* in Gulf of Mexico). BRIGGS, 1958, p. 294 (compiled range; [Cuba incorrect]). BULLIS AND THOMPSON, 1965, p. 53 (*Silver Bay* stations 127, 157, 461, and 1283). MOE, and others, 1966, p. 79 (specimens in Florida Board of Conservation collection).

NOMENCLATURAL REMARKS. Reasons for placing *Pontinus pollux* Poey in the synonymy of *P. castor* Poey are given under the account of *P. castor*. *Neomerinthe hemingwayi* Fowler is reinstated as a valid species. The record of *P. castor* in the Gulf of Mexico (Springer and Bullis, 1956: *Oregon* station 18) is inconsistent with the distribution as known for *P. castor* [see account of *P. castor*]; they report *N. hemingwayi* from nearby stations (9 and 35), so their identification is referred to *N. hemingwayi*. (One specimen examined is from *Oregon* station 10.)

MATERIAL EXAMINED. *Atlantic Coast of United States*. DELAWARE-MARYLAND: ANSP no. 63482 (1, about 300, holotype of *N. hemingwayi*) about 70 miles SE. of Cape May, New Jersey. GEORGIA: UMML no. 16226 (14, 102–208), UMML no. 14270 (5, 153–315), and UMML no. 14361 (4, 130–163) 31°59.5′ N., 79°11.5′ W., in 75–80 fathoms, *Silver Bay* station 5398; UMML no. 16228 (2, 149–164) and UMML no. 14265 (1, 155) 32°01′ N., 70°10′ W., in 80–75 fathoms, *Silver Bay* station 5397; TABL uncataloged (1) 31°32′ N., 79°42′ W., in 52–70 fathoms, *Silver Bay* station 3353; TABL uncataloged (1) 31°34′ N., 79°43′ W., in 30–40 fathoms, *Silver Bay* station 3765. FLORIDA: TABL uncataloged (1) 29°38′ N., 80°16′ W., in 50 fathoms, *Silver Bay* station 461. *Gulf of Mexico*. USNM no. 196765 (1, about 63) W. C. Renfro, no other data. FLORIDA: UMML no. 16200 (1, 218) 27°56′ N., 84°46′ W., in 100 fathoms, *Oregon* station 4083; UMML no. 16225 (5, 177–271) 29°42′ N.,

86°45′ W., in 100 fathoms, *Oregon* station 4943; USNM no. 108871 (1, 200, holotype of *N. tortugae*) and USNM 108872 (2, 108–175, paratypes of *N. tortugae*) south of Tortugas in 60 fathoms, W. H. Longley. Mississippi Delta: USNM no. 157671 (1, about 248) 28°45′ N., 89°43′ W., in 50 fathoms, *Oregon* station 10.

Description. Counts and measurements summarized in tables 1–9; body shape and coloration in figure 5a.

A moderately long-snouted species with 10 soft dorsal rays and no elongate dorsal spines. Dorsal fin with 12 spines and 10 (rarely 9) soft rays; pectoral rays 16–17 (usually 17), usually rays 3 through 7 or 8 (2–9) branched in larger specimens, one of 63 mm. S.L. with no branched rays. Gill rakers 6–7 on upper arch, 9–12 on lower arch including rudiments. Preorbital bone with 2 points over maxillary, first points out, second out and to rear. Suborbital ridge with 1 or no spines on preorbital and usually 3 on suborbitals, additional small points found in some larger specimens. First preopercular spine longest, second absent except in very small specimens, third and fourth moderate to small, fifth small to absent. Upper posttemporal spine usually absent. Other spines as for the genus. Vertebrae 24 (four specimens). Scales ctenoid. About 60–70 vertical scale rows. Dorsal part of head, pectoral-fin base, chest, and maxillary with small ctenoid scales. Supraocular tentacle less than one-third orbit diameter or absent. Orbit about equal to snout in smaller specimens and smaller than snout in larger specimens, ratio of snout divided by orbit 1.1–1.7; orbit into head 4.1 in smaller specimens to 5.2 in largest specimens; interorbital width into orbit diameter 1.6–2.3, smaller specimens tend to have higher values.

Coloration usually as in figure 5a. Blotches on sides better defined in small specimens; larger specimens more speckled. Dark pigment on inside of pectoral fin. A few dark spots often present in pectoral-fin axil. Pelvic fins dusky at distal end in smaller specimens.

A large species, largest specimen studied 315 mm. in standard length.

Comparisons. This species is easily distinguished from its western Atlantic congenor by the presence of 10 soft dorsal rays (9 or 8 in *N. beanorum*, rarely 9 in *N. hemingwayi*). The third dorsal spine is notably elongate in larger specimens of *N. beanorum* but not in *N. hemingwayi*. They differ in coloration and measurements as given in the accounts and tables.

Distribution. The species is known from Maryland, south around Florida, and in the northeastern Gulf of Mexico. Depths of capture range from 30 or 40 to 100 fathoms.

Neomerinthe beanorum (Evermann and Marsh).

Pontinus beanorum Evermann and Marsh, 1900, pp. 279–280, fig. 85 (type locality off San Juan Harbor, Puerto Rico, *Fish Hawk* station 6050, in 91 fathoms, holotype USNM no. 49534). Jordan, Evermann, and Clark, 1930, p. 372 (compiled). ?Howell Rivero, 1936, p. 63 (two specimens from off Havana, Cuba; no description).

Neomerinthe beanorum, Ginsburg, 1953, pp. 56–57 (description; 6 specimens from Puerto Rico). Bullis and Thompson, 1965, p. 53 (collections by U. S. Fish and Wildlife Service exploratory fishing vessels).

Material examined. Florida Straits off the Bahamas: UMML no. 17719 (1, 121) 25°55′–57′ N., 79°19′–18′ W., in 208 fathoms, *Gerda* station 626; UMML no. 17656 (1, 94) 25°52′–53′ N., 79°20′–19′ W., in 200–210 fathoms, *Gerda* station 507; UMML no. 17640 (1, 47) 25°49′–51′ N., 79°19′ W., in 128–118 fathoms, *Gerda* station 624. Cuba: USNM no. 157870 (3, 131–154) 22°59′ N., 79°17′ W., in 250 fathoms, *Oregon* station 1343; USNM no. 188196 (3) 23°34′ N., 79°05′ W., in 150 fathoms, *Silver Bay* station 2464. Jamaica: USNM no. 188194 (1) 17°50′ N., 77°52′ W., in 170 fathoms, *Oregon* station 3549; USNM no. 188203 (3) 17°53′ N., 77°56′ W., in 150 fathoms, *Oregon* station 3548. Dominican Republic: UMML no. 16227 (9, 75–144) 19°48.5′ N., 70°30.5′ W., in 220–300 fathoms, *Silver Bay* station 5166. Puerto Rico: USNM no. 49534 (1, 106, holotype of *N. beanorum*) off San Juan Harbor, in 91 fathoms, *Fish Hawk* station 6050; USNM no. 187913 (5, 77–132) 18°26′ N., 67°11.5′ W., in 175 fathoms, *Oregon* station 2658 (corrected station list); UMML no. 7432 (2, 101–108) 18°26′ N., 67°10.5′ W., in 150 fathoms, *Oregon* station 2653 (corrected list). Virgin Islands: UMML no. 7431 (3, 33–47) 18°13′ N., 64°14.5′ W., in 125 fathoms, *Oregon* station 2649 (corrected list). Honduras: USNM no. 188201 (5) 16°08′ N., 81°03′ W., in 105–110 fathoms, *Oregon* station 3623. Nicaragua: UMML no. 14003 (1, 75) 11°40′ N., 83°09′ W., in 90 fathoms, *Oregon* station 3580; USNM no. 184957 (1) 11°27′ N., 83°11′ W., in 135 fathoms, *Oregon* station 1902. Panama: USNM no. 188207 (16, 35–140) 9°18′ N., 80°27′ W., in 100 fathoms, *Oregon* station 3588; USNM no. 188200 (1, 93) 9°12′ N., 81°30′ W., in 135–140 fathoms, *Oregon* station 3585; USNM no. 188205 (10) 9°18′ N., 80°22′ W., in 125 fathoms, *Oregon* station 3590; USNM no. 188198 (4) 9°02′ N., 81°26′ W., in 100 fathoms, *Oregon* station 3595; UMML no. 22179 (5) 9°37.5′–37′ N., 78°54′–52.5′ W., in 70–35 fathoms, *Pillsbury* station 330; UMML no. 22197 (21) 9°59′ N., 76°02′–59.7′ W., in 24–71 fathoms, *Pillsbury* station 375; UMML no. 22194 (1) 9°45′–48′ N., 76°12′–9.6′ W., in 55–45 fathoms, *Pillsbury* station 372; UMML no. 22202 (1) 8°52.4′ N., 76°50.4′–51.5′ W., in 50–54 fathoms, *Pillsbury* station 400; UMML no. 22213 (2) 8°58.1′–56.1′ N., 81°26.3′–26.8′ W., in 163–60 fathoms, *Pillsbury* station 446. Colombia: UMML no. 17304 (1, 61) 10°00′ N., 76°05′ W., in 80–100 fathoms, *Oregon* station 4904; UMML no. 17315 (11, 54–108) 11°01.8′ N., 75°14′ W., in 35 fathoms, *Oregon* station 4872; UMML no. 22171 (2) 9°05.6′–07.2′ N., 76°32.1′–30.9′ W., in 96–64 fathoms, *Pillsbury* station 398. Venezuela: UMML no. 16704 (1, 73) 11°06.7′ N., 74°30′ W., in 100 fathoms, *Oregon* station 4844; UMML no. 16668 (4, 56–93) 11°08′ N., 74°23′ W., in 100 fathoms, *Oregon* station 4856.

Description. Counts and measurements summarized in tables 1–9; body shape and coloration in figure 5b.

A short-snouted, moderate-sized species usually with 9 soft dorsal rays and the third dorsal spine notably elongate in specimens over about 120 mm. in standard length. Dorsal fin with 12 spines and 9 (rarely 8) soft rays. Pectoral rays usually 17 (16–18), rays 3 or 4 through 7 to 9 branched in specimens over about 50 mm. in standard length. Gill rakers on upper arch 5–6, 9–11 on lower arch including rudiments. Preorbital bone with 2 spines over maxillary, first points down to slightly forward, second points back. Suborbital ridge with 3 or 4 spinous points, 3 on suborbital bones and 1 or none on preorbital bone. Second preopercular spine small or absent, third usually points down, fourth slightly forward, and fifth forward or absent. Upper posttemporal spine small. Other spines as for the genus. Vertebrae 24 (11 specimens). Scales on body weakly ctenoid; vertical scale rows about 40–45; scales on pectoral-fin base and chest mostly cycloid and partially buried; occipital area and cheek with large weakly ctenoid scales; nape and interorbital area naked. Supraocular tentacle absent or small, about equal to orbit diameter as maximum. Orbit about equal to snout, slightly larger than snout in smaller specimens to slightly smaller in large specimens, ratio snout divided by orbit 0.7–1.2; orbit into head 3.4–4.3, larger specimens with higher values; interorbital width into orbit diameter 2.3–3.5, larger specimens tend to have lower values.

Coloration as in figure 5b. Specimens often faded, but almost always retaining elongate dusky spots on the pectoral fins. Anal and pelvic fins usually clear, sometimes dusky at tips. Upper half of caudal fin and the soft dorsal fin spotted, lower half of caudal fin sometimes dusky near end of fin. Spinous dorsal fin usually with dark pigment at midheight of fin; dark pigment concentrated near end of spinous dorsal fin in small specimens.

A moderate-sized species, largest available specimen about 155 mm. in standard length.

Comparisons. See account of *Neomerinthe hemingwayi*.

Distribution. The species has been reported from Puerto Rico and Cuba. The range now includes the Bahamas side of the Florida Straits, and throughout the Caribbean (Cuba, Jamaica, Dominican Republic, Puerto Rico, Virgin Islands, Honduras, Nicaragua, Panama, Colombia, and Venezuela). Depths of capture range from about 50 to 205 fathoms (one lot from 35 fathoms possibly with incorrect data).

Neomerinthe folgori (Postel and Roux).

Scorpaena sp. Cervigon, 1960, p. 95, fig. 54 on p. 97 (one specimen from off Mauritania at 19°04′ N., in 310 meters).

Scorpaena folgori Postel and Roux, 1964, pp. 167–170, figs. 1–2 (type locality Cape Verde Islands, Accores de Brava, in 180–200 meters; type in Museum National d'Histoire Naturelle, Paris).

MATERIAL EXAMINED. IIP uncataloged (1, 340), the specimen reported by Cervigon (1960, p. 95) [See above].

DESCRIPTION. (Based on one specimen and information in the original description.) Counts and measurements summarized in tables 1–10.

Dorsal fin with 12 spines and 11 soft rays (last double). Pectoral fin with 17 rays, upper 2 unbranched, next 6 branched once, lower 9 simple. Gill rakers short and stubby, total 19 including rudiments; 7 on upper arch. Most spines on head variously divided into several points (not to be expected in small specimens). Preorbital bone with 2 spinous lobes over maxillary, several points on each. Suborbital ridge with many small points. Supplemental preopercular spine present; first preopercular spine longest; second usually absent (small on left in specimen examined); third and fourth present (divided); fifth virtually absent. Upper posttemporal spine small or absent. Other spines as for the genus. Vertebrae 24 (one specimen). Scales on body ctenoid, about 85 vertical scale rows. Tubed lateral-line scales 27+1. Dorsal part of head, pectoral-fin base, and maxillary with small ctenoid scales; partially embedded, mostly cycloid, scales present on chest. Tentacles on body and head poorly developed. Small appendages associated with posterior preorbital lobe, preocular, supra-ocular, and fifth preopercular spines, and on a few lateral-line scales. In specimen examined, orbit smaller than snout, ratio snout divided by orbit 1.7; orbit into head 5.5 (smaller specimens should have a proportionally larger orbit); interorbital width into orbit diameter 1.6.

Coloration of preserved specimens mostly pallid. Indication of some dark pigment on body below soft dorsal fin, below middle of spinous dorsal fin, and at front of dorsal fin. Spinous dorsal fin with dark pigment on membranes, more concentrated at anterior part of fin and at about mid-height of fin. The figure of the type (Postel and Roux, 1964, fig. 1) shows the tip of the caudal fin black; it is clear in my specimen. Color in life according to Postel and Roux is generally reddish.

DISTRIBUTION. Known from the Cape Verde Islands (holotype) in 180–220 meters and from the coast of Africa at Mauritania in 310 meters. The type was taken in a lobster trap which suggests that the habitat is rough-bottom. No specimens were collected by Boutiere in trawling off Morocco, and none was collected in the Gulf of Guinea. Postel and Roux (p. 170) report that according to the fishermen the species is rare about the Cape Verde Islands.

REMARKS. The specimen examined agrees well with the description of the holotype. Postel and Roux report the soft dorsal rays as 12, but this results from counting the last double ray as 2. Measurements are similar except for the interorbital width (5.5 versus 7 percent); my lower value is the least width of the interorbital and was probably taken further forward than their measurement. The difference in pigmentation of the caudal fin is discussed above. Another difference which is probably due to differences in sizes of specimens

is that the pelvic fin reaches the anus in their specimen but falls short of the anus in my specimen. They refer to a characteristic tricuspid process in the preocular area which is curved to the rear; this is the posterior preorbital spinous lobe (Matsubara's terminology) which is possibly single in small specimens. The degree of bifurcation of spines is less in their specimen.

The species *Scorpaena folgori* Postel and Roux (1964) differs from species of *Scorpaena* and agrees with species of *Neomerinthe* in having a swimbladder and having a slit behind the fourth gill arch. The two species now included in *Neomerinthe* have 8–10 soft dorsal rays, while "*folgori*" has 11. In other characters, "*folgori*" appears to agree with species now included in *Neomerinthe*. The genus *Neomerinthe* is closely related to *Pontinus*, differing from species of *Pontinus* in having some pectoral rays branched; the branching is simple, rather than the double or triple branching that one finds in most adults of other species of the subfamily Scorpaeninae.

Genus **Trachyscorpia** Ginsburg

Trachyscorpia Ginsburg, 1953, pp. 57–59 (type-species *Scorpaena cristulata* Goode and Bean, by original designation).

Diagnosis. Dorsal rays XII (XI), 8–9 in subgenus *Trachyscorpia* and XIII, 8–9 in subgenus *Mesoscorpia;* anal rays normally III, 5; pectoral rays 20–24, some rays branched, branching compound, longest rays near upper part of fin; lower part of pectoral fins, pelvic fins, and anal fin fleshy in large specimens; swimbladder absent; vertebrae 25 in subgenus *Trachyscorpia* and 26 in subgenus *Mesoscorpia;* scales on body ctenoid; cheek, postorbital area, and occiput scaled; no occipital pit; no slit behind fourth gill arch; palatine teeth present; peritoneum black.

Spination. Most spines on head well developed. Preorbital bone with 2 spines over maxillary, first points out, second points out and back. Suborbital ridge prominent, with sharp spines; basically 1 or 2 spinous points on preorbital and 5 or so on the suborbitals (many suborbital spinous points often variously divided, especially in larger specimens, with about 25 points in one specimen of *T. c. cristulata*). Supplemental preopercular spine present; first preopercular spine long; second slightly closer to first than to third; fourth present; fifth small to virtually absent. Upper posttemporal spine absent. Other spines present include nasal, pre-, supra-, and postocular, tympanic, parietal, nuchal, pterotic, sphenotic, lower posttemporal, supracleithral, and cleithral.

Remarks. *Scorpaena capensis* Gilchrist and Von Bonde is included in the present genus but as a separate subgenus, *Mesoscorpia*, as discussed below. In the subgenus *Trachyscorpia* one species consisting of two subspecies, is recognized.

In general, the number of dorsal spines, especially when 12 or 13, is very important at the generic level as felt by Cadenat (1945), but in this case I

agree with Norman (1935b, p. 32) that *Scorpaena capensis* is congeneric with "*cristulata*" (or at least more closely related to "*cristulata*" than to other species); "*cristulata*" subsequently (Ginsburg, 1953) was removed from the genus *Scorpaena* and placed in the genus *Trachyscorpia*.

The species "*capensis*" appears to agree with *Trachyscorpia* in most characters, differing mainly in having one more dorsal spine and one more vertebra. The two species, "*capensis*" and *T. cristulata*, share several features which are of rare occurrence in the family Scorpaenidae such as the characteristic bilobed shape of the pectoral fins, lower pectoral rays and pelvic and anal fins fleshy in larger specimens, extra large anterior foramina on the frontal bones between the orbits, and extra large median depression present at the middle portion of the frontal bones. These same characters are shared by the species treated by Matsubara (1943, p. 326) in the subfamily Sebastolobinae (one genus, *Sebastolobus*); species of this subfamily, which occur in the North Pacific, have more primitive suborbital bones than species of *Trachyscorpia*, though the second suborbital bone is identical in shape, and species of *Sebastolobus* also have more vertebrae (27–30) and dorsal spines (15–17). Matsubara treated the Sebastolobinae as close to the Scorpaeninae. An osteological comparison is needed, but from radiographs *T. capensis* and *T. cristulata* do not seem to differ significantly from species of Sebastolobinae in other characters, and probably will be shown to belong in the Sebastolobinae rather than in the Scorpaeninae.

Subgenus **Trachyscorpia** Ginsburg

TYPE-SPECIES. *Scorpaena cristulata* Goode and Bean, 1896, by original designation.

DIAGNOSIS. Dorsal spines normally 12; vertebrae 25.

Trachyscorpia cristulata (Goode and Bean).

REMARKS. Koehler (1896, p. 478) described the species *Scorpaena echinata* but on a subsequent page (524) in the same work stated in a footnote that his eastern Atlantic species was the same as the species *S. cristulata* described by Goode and Bean (1896) from the western Atlantic. Since that time, both the names "*echinata*" and (more frequently) "*cristulata*" have been used for specimens from the eastern Atlantic. Ginsburg (1953) described the genus *Trachyscorpia* and recognized both *T. echinata* and *T. cristulata* as valid species. However, the single specimen from the eastern Atlantic available to Ginsburg appears to be unusual in some characters, and the differences between specimens from the eastern and western Atlantic would seem to be of about subspecific value or less. Direct comparison of specimens of similar sizes is needed. Ginsburg's specimen from the eastern Atlantic had 20 pectoral rays, while his specimens from the western Atlantic had 22–24, but Boutiere (1958, p. 71) reports pectoral-ray counts for 10 specimens from Mauritania as 21 (3), 22 (6), and

23(1). Counts for 21 specimens from the western Atlantic are 22 (2, one with 21 on right), 23 (17), and 24 (2). Ginsburg's specimen from the eastern Atlantic also had 8 soft dorsal rays, while the most frequent count is 9 (of 20 specimens from the western Atlantic, 2 had 8; Boutiere's specimens from the eastern Atlantic had 8 (four specimens) or 9 (5), when last double ray counted as one). The color pattern as shown by Boutiere (1958, pl. 5b) for a specimen from Mauritania is identical with that of large males from the western Atlantic. Specimens from the eastern Atlantic do appear to have a smaller head than similar-sized specimens from the western Atlantic; other measurements, such as orbit diameter, appear to be correspondingly smaller also. A large series of specimens is needed to evaluate differences in measurements as some values change considerably with growth. Tentatively the eastern and western Atlantic populations are treated as separate subspecies, but if the differences prove to be as small as they seem, subspecies recognition may not be warranted. This species is one of the deeper-living of scorpionfishes, and it would appear easy for this temperate species to cross the North Atlantic. The two subspecies are treated separately below.

Trachyscorpia cristulata cristulata (Goode and Bean).

Scorpaena cristulata Goode and Bean, 1896, pp. 246–247, pl. 67, fig. 242 (type locality off Georgia, *Albatross* station 2415, 30°44′ N., 79°26′ W., in 440 fathoms, USNM no. 39326). Jordan and Evermann, 1898, pp. 1841–1842 (compiled). Jordan, Evermann, and Clark, 1930, p. 372 (included "*echinata*" [misspelled as "*echinita*"]).

Trachyscorpia cristulata, Ginsburg, 1953, pp. 61–63 (description; compared with *T. echinata*; 13 specimens from Atlantic coast of U. S., from Massachusetts to Florida, in 72–440 fathoms). Springer and Bullis, 1956, p. 91 (Gulf of Mexico). Briggs, 1958, p. 294 (range compiled). Bullis and Thompson, 1965, p. 54 (collections by U. S. Fish and Wildlife Service exploratory fishing vessels).

Material examined. (Unless otherwise stated the stations refer to *Oregon* stations.) Georgia: USNM no. 39326 (1, 144, holotype) 30°44′ N., 79°26′ W., in 440 fathoms, *Albatross* station 2415. Florida Atlantic Coast and Florida Straits: UMML no. 575 (1, 106) 29°01′ N., 79°58′ W., in 165–212 fathoms, *Pelican* station 29; UMML no. 20798 (1, 162) 25°39′–41′ N., 80°00′–01′ W., in 169–162 fathoms, *Gerda* station 766; UMML no. 12559 (1, 62) 25°30′–45′ N., 79°58′–51.5′ W., in 180 fathoms, *Gerda* station 197; UMML no. 16205 (2, 144–191) 24°29′ N., 83°29′ W., in 190 fathoms, station 4336; UMML no. 16221 (1, 237) 24°28′ N., 83°26′ W., in 225 fathoms, station 4363; UMML no. 13732 (2, 75–116) 24°26′ N., 83°31′ W., in 300 fathoms, station 4373; UMML no. 16217 (3, 62–253) 24°25′ N., 83°29′ W., in 300 fathoms, station 4145; UMML no. 14287 (1, 202) 23°53′ N., 83°13′ W., in 600 fathoms, station 4562; UMML no. 14268 (1, 259) 23°51′ N., 83°17′ W., in 600 fathoms, station 4563; UMML 16215 (1, 229) 24°27′ N., 83°25′ W., in 210 fathoms, station 4359; UMML no. 16218 (2, 185–225) 24°30′ N., 83°33′ W., in 190

fathoms, station 4362; ANSP no. 103415 (1, 153) 29°50′ N., 80°10′ W., in 155–175 fathoms, *Silver Bay* station 1604. Northern Gulf of Mexico: UMML no. 22222 (1, 352) 29°23′ N., 87°25′ W., in 250 fathoms, station 4947; UMML no. 22223 (2, 345–350) 29°02′ N., 88°34′ W., in 220 fathoms, station 4824.

Description. Counts and measurements summarized in tables 1–9; body shape and coloration in figure 6a, b.

Dorsal fin with 12 spines and 9 (rarely 8) soft rays. Pectoral fin with 21–24 rays (modally 23) rays 2–12 to 2–14 branched in specimens over about 100 mm. standard length, compound branching of some rays; pectoral fin with a characteristic shape, with the longest rays near upper part of fin and fin slightly bilobed; lower pectoral rays and pelvic and anal fins fleshy in large specimens. Vertebrae 25 (10 specimens).

Spination as for the genus. Scales on body ctenoid, about 60–65 (57–67) vertical scale rows. Snout usually naked; interorbital area, cheek, maxillary, pectoral-fin base, and chest scaled, some scales partially embedded and cycloid. Tentacles poorly developed, supraocular tentacle slender and tiny to absent. Orbit larger than snout in small specimens to about equal to snout in large specimens, ratio snout divided by orbit 0.6–1.0; orbit into head about 3.1–3.2 in smaller specimens to 4.0 in large specimens; interorbital width into orbit diameter 1.7–3.5, larger specimens with lower values.

Coloration as in figure 6a, b. Usually some dusky pigment on back and sides, especially below the third or fourth to tenth dorsal spines and below the soft dorsal fin, with a paler area below the tenth to twelfth spines. Inside of pectoral fin often with dusky pigment. Spinous dorsal with dusky pigment between about spines 5 or 7 to 11; this area black in males (fig. 6a) and brown in females and smaller specimens (fig. 6b). Soft dorsal fin, caudal fin, and anal fin frequently dusky, especially in larger specimens. The peritoneum is mostly black in life.

A large species probably reaching 400 or 500 mm. in standard length, largest available about 350 mm.

Distribution. This subspecies is known from Massachusetts to the Florida Straits and in the northern Gulf of Mexico. Depths of capture range from 72 to 600 fathoms.

Trachyscorpia cristulata echinata (Koehler).

Scorpaena echinata Koehler, 1896, p. 478, pl. 27, figs. 4–6 (type locality Bay of Biscay, 45°57′ N., 6°21′ W., in 1,275 meters). Norman, 1935a, p. 614 (compiled). Norman, 1935b, p. 32 (description; comparisons).

Scorpaena cristulata, *Koehler*, 1896, p. 524 (states in footnote that "*echinata*" equals "*cristulata*" Goode & Bean). Holt and Byrne, 1908, pp. 20–25, pl. 2 (good description; off southwest Ireland in about 500–800 fathoms). Koeford, 1927, p. 131 (*Michael Sars* station 4, 49°38′ N., 11°35′ W., in 923 meters, 3 specimens 38–50 cm.; brief description; synonymy). Cadenat, 1945, pp. 535–537 (good description; comparisons). Boutiere,

1958, p. 12, and following, pls. 1c, 5a (coast of Morocco; life history notes; figure good). Collignon and Aloncle, 1960, p. 25 (food). Lozano Cabo, 1963, p. 345 (listed; Spanish Sahara-Mauritania).

Sebastes kuhlii (not of Bowdich), Vaillant, 1888, pp. 370–373 (measurements and pectoral-ray count are of *T. c. echinata*; description of otoliths; 65 specimens from coast of Africa in 140–2330 meters [specimens from shallower depths are possibly a different species]). Grey, 1956, p. 222 (depth distribution based on Vaillant's record of specimen from 2330 meters).

Trachyscorpia echinata, Ginsburg, 1953, pp. 59–61 (placed in new genus; description from a specimen from southwest coast of Ireland; compared with *T. cristulata* [see Remarks under genus]).

Trachyscorpia cristulata, Maurin, 1962, p. 206 (collections in Mediterranean; 500–600 meters).

Description. As for *Trachyscorpia cristulata cristulata* with the following exceptions. This subspecies averages fewer pectoral rays, 20–23 (modally 22) and appears to have a slightly smaller head as well as smaller measurements of head parts (for example, orbit diameter) when expressed as percent standard length; or, conversely, the body is proportionally longer in this subspecies.

Distribution. This subspecies is known from Ireland south to Mauritania in depths from about 60 to 1290 fathoms. It was not collected in the Gulf of Guinea. The subspecies in the western Atlantic also tends to be temperate in distribution. This species is reported from deeper depths than any other scorpaenid.

Subgenus **Mesoscorpia** Eschmeyer, new subgenus

Type-species. *Scorpaena capensis* Gilchrist and Von Bonde, 1924, here treated as *Trachyscorpia* (*Mesoscorpia*) *capensis*.

Diagnosis. Differs from subgenus *Trachyscorpia* by the presence of 26 rather than 25 vertebrae and normally 13 rather than 12 dorsal spines. The tympanic spines are absent in subgenus *Mesoscorpia* and present in subgenus *Trachyscorpia*. [See also Remarks under the genus.]

Etymology. The subgeneric name is based on the Greek word middle + *scorpia*, referring to the apparent intermediate status of the type-species between species of the subfamily Sebastolobinae and the genus *Trachyscorpia*.

Trachyscorpia capensis (Gilchrist and Von Bonde).

Scorpaena capensis Gilchrist and Von Bonde, 1924, pp. 18–19 (type locality west coast of South Africa at *Pickle* stations 66, 86, and 336, in 280–537 fathoms; three specimens to 270 mm.). Cadenat, 1945, p. 534 (not related to *Scorpaena;* no specimens).

Sebastosemus capensis, Barnard, 1927, pp. 909–911 (placed questionably [wrongly] in *Sebastosemus* Gill; description; allied to *Scorpaena echinata*; type in collection of Government Marine Survey; [small specimen with 12 dorsal spines probably not this species]). Smith, 1949, p. 372, fig. 1044 (brief description; to 12 inches in length; from Cape to Saint Helena Bay, in 250–560 fathoms).

Scorpaena (??) *capensis*, Norman, 1935b, p. 32 (thought related to *Scorpaena echinata* and *S. cristulata*, and that 13 dorsal spines not an important difference) p. 53 (two specimens of 370–400 mm., from 34°08′ S., 17°33′ E., in 402–?548 meters).

MATERIAL EXAMINED. BMNH no. 1935.5.2.10 (1, 320) South Africa, 34°08′ S., 17°33′ E., in 402–?548 meters, Cape trawler *Richard Bennet*, collected 8 July 1927. (Specimen in poor condition.)

DESCRIPTION. (Partially compiled.) Measurements and counts for the single specimen examined in tables 1–9; body shape and coloration in figure 5c.

Dorsal fin normally with 13 spines and 8–9 (usually 9) soft rays. Anal fin normally with 3 spines and 5 soft rays. Pectoral rays 20–23, upper 1 or 2 and lower 6–9 simple in larger specimens; middle rays with compound branching, lower rays very fleshy in large specimens; longest rays near upper part of fin. Ventral and anal fins also fleshy in large specimens. Gill rakers including rudiments 4–5 + 10–12, all fairly short and somewhat difficult to count at upper and lower ends. Vertebrae 26 in specimen examined.

Preorbital bone with 2 spinous points over maxillary, pointing out or slightly to rear. Suborbital ridge prominent, spinous; 1 or 2 spines on preorbital and 4–6 poorly defined spinous points on suborbitals (variability expected in suborbital spination). Tympanic spines absent. Other spines as for the genus.

Scales on body ctenoid, about 60 vertical scale rows; tubed lateral-line scales about 26 + 3. Snout naked; interorbital area, cheek, maxillary, pectoral-fin base, and chest scaled; scales often partially embedded on chest. Tentacles absent in available specimen. Orbit large, specimen examined with orbit diameter into snout 0.7 (orbit may be proportionally larger in smaller specimens); orbit diameter into head length 3.4 (smaller specimens will probably have lower values); interorbital width into orbit diameter 4.8 (smaller specimens will probably average higher values).

The available specimen not differing much in coloration from *T. cristulata*. The spinous dorsal with dark pigment over most of its length; the soft dorsal fin and pectoral fins with brown pigment. (Most scales are missing from the body obscuring the pigmentation.) Some scattered dusky smudges on the head. Peritoneum darkly pigmented.

COMPARISONS. Besides the differences in number of dorsal spines, vertebrae, and presence or absence of tympanic spines, *T. capensis* differs from *T. cristulata* in having the posterior roof of the cranium broader and flatter. Some differences in measurements are shown in the tabular data.

DISTRIBUTION. Known only from the southwestern tip of South Africa. Specimens have been collected in depths from about 200 to 550 fathoms.

Genus **Phenacoscorpius** Fowler

Phenacoscorpius FOWLER, 1938, pp. 69–70 (type-species *Phenacoscorpius megalops* Fowler, by original designation; monotypic). NORMAN, 1939, p. 94 (one new species added). SMITH, 1957a, p. 69 (probably incorrectly included a new species). ESCHMEYER, 1965b, pp. 522–523 (genus redescribed; one new species added).

DIAGNOSIS. Dorsal rays XII, 9; anal rays III, 5: pectoral rays 15–17, some

rays branched; swimbladder present; vertebrae 25; scales on body ctenoid; cheek, occiput, and pectoral base scaly; scales on cheek and belly cycloid; lateral line incomplete, only anterior 3–6 tubed scales present; no occipital pit; teeth on palatines present in a small patch or absent; slit behind fourth gill arch tiny in the western Atlantic species; peritoneum pallid.

Spination. (Applies to the Atlantic species.) Most spines on head well developed. Preorbital bone with two spinous points over maxillary, first rounded, second broadly pointed. Suborbital ridge with 5–8 spinous points in available Atlantic specimens. Supplemental preopercular spine present; first, third, fourth, and fifth preopercular spines present, second small or absent. Upper posttemporal spine present. Other spines present include nasal, pre-, supra-, and postocular, tympanic, parietal, nuchal, pterotic, sphenotic, lower posttemporal, supracleithral, and cleithral.

Phenacoscorpius nebris Eschmeyer.

(See Eschmeyer, 1965b, pp. 522–525, fig. 1, for a detailed treatment.)

Phenacoscorpius nebris Eschmeyer, 1965b, pp. 522–525, fig. 1 (type locality Peninsula de Guajira, Venezuela, 12°46′ N., 70°59′ W., in 190 fathoms, *Oregon* station 4396).

Correction of locality data. The holotype of this species was correctly reported from Venezuela, but subsequent information shows that the two paratypes are also from Venezuela and not from the northern Gulf of Mexico as reported in the original description. Tomio Iwamoto recently provided color slides of scorpionfishes which he took while working for the Fish and Wildlife Service Bureau of Commercial Fisheries on the vessel *Oregon*. Two of the slides depict the two paratypes, and his notes show that they were from *Oregon* station 4453. The station number on the label with the specimens was *Oregon* 4780, a fish trap station in the northern Gulf of Mexico in 35 fathoms. Iwamoto has informed me that the fish traps used were of too coarse a mesh to retain fishes of the size of the paratypes, and he feels that his notes listing the station as 4453 are correct. The specimens were definitely taken during the cruise off Venezuela. The locality data for station 4453 are as follows: 10°54′ N., 67°08′ W., in 220 fathoms, 40-foot flat trawl. The holotype was collected in a similar depth (190 fathoms) and slightly further west at 12°46′ N., 70°59′ W. (The additional specimens reported below are, however, supposed to be from the Gulf of Mexico.)

Additional material. USNM no. 159148 (4, 59–81) and 159149 (3, 67–81) 29°06′ N., 88°19′ W., in 260 fathoms, *Oregon* station 1283.

Additional information. The slides of the paratypes show the specimens have the head and body pinkish-red. The caudal fin and soft dorsal fin are spotted with darker red. The pectoral fins are not in focus but appear to be spotted with red. The iris is reddish in color.

The additional specimens agree well with the types. The second preopercular

spine is present in some specimens, and more suborbital spinous points are also present in some of the additional specimens. Counts are entered in tables 1–2.

Genus **Idiastion** Eschmeyer

Idiastion Eschmeyer, 1965b, p. 530 (type-species *Idiastion kyphos* Eschmeyer, by original designation; one species).

Diagnosis. Dorsal rays XII, 9; anal rays III, 5; pectoral rays 17–18 (two specimens); swimbladder present; vertebrae 25; scales ctenoid; head scaled between orbits, along suborbital ridge, on cheeks, and opercle; spines strongly developed, often multiplicate; no occipital pit; teeth on palatines; small slit behind fourth gill arch; peritoneum pale.

Spination. Preorbital bone with 2 spines over maxillary, first blunt, second sharp. Suborbital ridge with numerous spinous points (two known specimens with 5 or more on suborbitals and 3 on preorbital). Supplemental preopercular spine present; first preopercular spine longest; second tiny or absent, third, fourth, and fifth point mostly towards rear. Upper posttemporal spine absent. Other spines present include nasal, pre-, supra-, and postocular, tympanic, parietal, nuchal, pterotic, sphenotic (as group of small spines), lower posttemporal, supracleithral, and cleithral.

Remarks. The genus is based on one species which is known from two specimens. Most species in the subfamily Scorpaeninae have 24 vertebrae, but species of three genera within the subfamily have 25 vertebrae, *Idiastion*, *Phenacoscorpius*, and *Trachyscorpia* (25 or 26). *Idiastion* differs from *Trachyscorpia* in the shape of the pectoral fin, presence of a slit behind the fourth gill arch, pallid peritoneum, and in body shape. *Phenacoscorpius* is characterized by an incomplete lateral line, but is similar to *Idiastion* in most other features. These genera contain species which live offshore; and compared to such shallow-water genera as *Scorpaena* and *Scorpaenodes*, speciation has been limited.

Idiastion kyphos Eschmeyer.

(See Eschmeyer, 1965b, pp. 530–533, figs. 3–5, for a detailed treatment.)

Idiastion kyphos Eschmeyer, 1965b, pp. 530–533, figs. 3–5 (type locality southeastern Caribbean Sea between Venezuela and Grenada, 11°40′ N., 62°33′ W., in 320–340 fathoms, *Oregon* station 5039).

Additional material. UMML no. 14016 (1, 53) off Venezuela, 11°46′ N., 69°17′ W., in 240 fathoms, *Oregon* station 4425.

Remarks. The original description is modified by the additional specimen as follows. This specimen has 17 pectoral rays while the type has 18. The vertebrae also number 25 as in the type. The type has many split spines, while this smaller specimen, as expected, does not. Spines on the suborbital ridge are also numerous, with 5 on the suborbitals in line with 3 on the preorbital bone. As in the type the anterior preorbital spine is rounded and the posterior

one pointed. Gill rakers number 19 (18 in the type), 6 on the upper arch increasing in size to angle, 10 rakers plus 3 smaller rudiments on the lower arch. Most scales are rubbed off in the specimen. The body and head, as in the type, are pallid with a few scattered small dark specks on the fins. Other characters are as in the type. Measurements of the smaller specimen in percent standard length are: head 46; depth 38, orbit 15, snout 11, interorbital 6, jaw 22, predorsal 45, length pectoral fin 32, length pelvic fin 24, length caudal fin 21. The type was captured in 320–340 fathoms, while the second specimen was collected in 240 fathoms.

Genus **Scorpaena** Linnaeus

Scorpaena Linnaeus, 1758, p. 266 (type-species *Scorpaena porcus*, by subsequent designation, Bleeker, 1876, p. 295).

Remarks. Currently the nominal genera *Sebastapistes* Gill and *Parascorpaena* Bleeker are included in *Scorpaena*, but the limits of the genus are broad and study on a world-wide basis is needed. Western Atlantic species were treated in detail earlier (Eschmeyer, 1965a).

Diagnosis. Dorsal rays normally XII, 9 (7–10, 8 normal for some species), anal rays normally III, 5; pectoral rays 16–21, some rays branched, the branching usually compound in larger specimens; swimbladder absent, vertebrae 24; scales on body cycloid or ctenoid, cycloid in western Atlantic species, mostly ctenoid in eastern Atlantic; occipital pit usually present; palatine teeth present; no slit behind fourth gill arch; peritoneum pallid.

Spination. Preorbital bone with 1–4 spinous points over maxillary. Suborbital ridge with 0 to several spines. Supplemental preopercular spine usually present; first preopercular spine longest; second and third present; fourth and fifth present or virtually absent. Upper posttemporal spine usually present. Nasal spine rarely absent. Other spines present include the pre-, supra-, and postocular, tympanic (usually absent in *S. grandicornis*), parietal, nuchal, pterotic, sphenotic (usually as group of spines), lower posttemporal, supracleithral, and cleithral (rarely absent). A few small spinous points usually present on fourth suborbital (the postorbital spines of Ginsburg, 1953).

Scorpaena isthmensis Meek and Hildebrand.

(See Eschmeyer, 1965a, pp. 103–107, fig. 5, for a detailed treatment.)

Scorpaena isthmensis Meek and Hildebrand, 1928, pp. 842–843, pl. 80 (type locality Porto Bello, Panama).

Additional references.

Scorpaena isthmensis, Cervigon, 1966, pp. 766–767, fig. 324 (description; Venezuela).

Scorpaena bergi, Caldwell and Caldwell, 1964, p. 39 (misidentified; Aruba and Colombia).

Distinguishing features. A moderate-sized species characterized by a spot on the spinous dorsal fin, no spinous points on the suborbital ridge, and pectoral ray count of usually 18–19.

ADDITIONAL INFORMATION. Vertebrae 24 in 8 specimens.

DISTRIBUTION. A coastal species known from Panama to Rio de Janeiro, Brazil. The species is evidently rare from Panama to Colombia; in *Pillsbury* operations during the summer of 1966, we took no specimens from Panama (at 81°31′ W.) to Cartagena, Colombia. The holotype is the only known specimen from west of about 71° W.

Scorpaena bergii Evermann and Marsh.

(See ESCHMEYER, 1965a, pp. 101–103, fig. 6a, for a detailed treatment.)

Scorpaena bergii EVERMANN AND MARSH, 1900, pp. 276–277, fig. 83 (type locality Mayagüez, Puerto Rico).

ADDITIONAL REFERENCES.

Scorpaena bergi, BULLIS AND THOMPSON, 1965, p. 53 (collections by U. S. Fish and Wildlife Service exploratory fishing vessels). BÖHLKE AND CHAPLIN, 1968, p. 646, fig. (description; Bahamas).

DISTINGUISHING FEATURES. A small species (to about 100 mm. in standard length) characterized by a spot on the spinous dorsal fin (sometimes poorly marked), one spine at the end of the suborbital ridge, and a pectoral ray count of 16–17.

ADDITIONAL MATERIAL. Two specimens in the Tropical Atlantic Biological Laboratory add two additional localities, *Silver Bay* station 3503 (Greater Inagua) and station 1220 (North Carolina).

ADDITIONAL INFORMATION. Vertebrae 24 in 8 specimens.

DISTRIBUTION. A clear-water species known from New York (outside normal range), North Carolina south to Florida, the Bahamas, Cozumel, Greater and Lesser Antilles, Dutch West Indies, and Bahia, Brazil.

Scorpaena petricola Eschmeyer.

(See ESCHMEYER, 1965a, pp. 107–109, fig. 6b, for a detailed treatment.)

Scorpaena petricola ESCHMEYER, 1965a, pp. 107–109, fig. 6b (type locality off Brazil, 1°59′ S., 42°05′ W., in 40 fathoms, *Oregon* station 4239).

REMARKS. A small species still known from the type material from off Brazil. The species is characterized by a generally pallid head and body and by the characters presented in the key.

ADDITIONAL INFORMATION. Vertebrae 24 in 9 specimens.

Scorpaena melasma Eschmeyer.

(See ESCHMEYER, 1965a, pp. 109–111, fig. 6c, for a detailed treatment.)

Scorpaena melasma ESCHMEYER, 1965a, pp. 109–111, fig. 6c (type locality off Brazil, 2°10′ S., 41°33′ W., in 36 fathoms).

ADDITIONAL INFORMATION. Vertebrae 24 in 1 specimen (paratype).

REMARKS. The species is still known only from the holotype and paratype collected off Brazil. The species is characterized by the combination of absence of a supplemental preopercular spine and presence of an occipital pit.

Scorpaena brachyptera Eschmeyer.

(See Eschmeyer, 1965a, pp. 111–114, figs. 7a, b, for a detailed treatment.)

Scorpaena brachyptera Eschmeyer, 1965a, pp. 111–114, figs. 7a, b (type locality off Venezuela, 10°50′ N., 66°55′ W., in 53 fathoms, *Oregon* station 4461).

Additional reference.

Scorpaena brachyptera, Cervigon, 1966, pp. 943–944 (description; Venezuela; three specimens from 30 fathoms; dorsal fin with 8 soft rays; pectoral fin rays 20/20).

Additional material. Florida: UMML no. 18648 (1, 44) 25°02.5′ N., 80°18.8′ W., in 39–40 fathoms, *Gerda* station 600. Panama-Colombia: UMML no. 22205 (1, 39) 9°33.8′–34.7′ N., 78°36.2′–36.7′ W., in 40–38 fathoms, *Pillsbury* station 422; UMML no. 22207 (1, 38) 9°31′–30.5′ N., 79°51′–52.5′ W., in 35–33 fathoms, *Pillsbury* station 430; UMML no. 22206 (1, 34) 9°43.7′ N., 79°22.2′ W., in 25 fathoms, *Pillsbury* station 428; UMML no. 22182 (1, 30) 9°37.5′–37′ N., 78°54′–52.5′ W., in 70–35 fathoms, *Pillsbury* station 330; UMML no. 22201 (1, 28) 9°45.1′–45.4′ N., 76°09.1′–10.8′ W., in 43–41 fathoms, *Pillsbury* station 392; UMML no. 22195 (1, 24) 9°45′–48′ N., 76°12′–9.6′ W., in 55–45 fathoms, *Pillsbury* station 372. Venezuela: USNM no. 201182 (1, 49) NE. part of Cariaco Trench, in 40 fathoms, vessel *Atlantis*; USNM no. 201180 (1, 38) 12°32′ N., 82°25′ W., in 85 fathoms, *Oregon* station 3577.

Remarks. This species was described by me (1965a) from five specimens collected by the *Oregon* off Venezuela in 40–65 fathoms. The additional specimens plus the type specimens give the following ranges for counts and measurements. Dorsal fin with 12 spines and 8 (12 specimens), 7 (1), or 9 (1) soft rays. Anal fin with 3 spines and 5 soft rays. Pectoral fin with 19 (6) or 20 (8) rays. Vertebrae 24 in four specimens. Gill rakers 10–12; 3–4 (usually 4) on upper arch, 7–8 on lower arch with lower-most ones as rudiments. Measurements in percent standard length: head 47–51, depth 38–42, orbit 13–16, snout 10–13, interorbital 5–7, jaw 24–26, predorsal 41–46, pectoral fin 26–32, caudal fin 29–36. In the original description the nasal spine was reported as absent. In some of the additional specimens there is a tiny nasal spine, sometimes only on one side. The nasal bones are freely movable, while in most other species the nasal bones are firmly attached by cartilage and support a larger nasal spine.

The short pectoral fin was used as a key character (Eschmeyer, 1965a), but some of the additional specimens have proportionally longer pectoral fins than the types, so this character is abandoned.

All additional specimens have a large dermal flap on the eye between the transparent and opaque portions. Also, they have the flap under the end of the suborbital ridge, the long tentacles on some lateral-line scales, and at the posterior preorbital spine. The preocular tentacle in some of the specimens is about equal to the orbit diameter, while the supraocular tentacle is smaller; both of these tentacles are often absent.

The pigmentation of the additional specimens is about as in the types.

Additional color notes based on the small specimen from *Pillsbury* station 428 are as follows: upper inside half of pectoral fin yellow; head with red, dusky, and some yellow pigment; iris yellowish-red; anal fin mottled with red, more concentrated on anterior half and at end of fin.

The pigment behind the head is concentrated in a poorly defined blotch above the pectoral fin in some specimens. The large preorbital tab is dusky in some specimens to unpigmented in others.

DISTRIBUTION. The species is now known from Venezuela, Colombia, Panama, and Florida. The specimen from Florida was taken in a dredge on a rock-rubble bottom. My notes for the specimens from off Panama and Colombia show at least some were taken in sponge-rich areas. The depths of capture range from 25 to about 65 fathoms.

Scorpaena elachys Eschmeyer.

(See ESCHMEYER, 1965a, pp. 114–116, fig. 7c, for a detailed treatment.)

Scorpaena elachys ESCHMEYER, 1965a, pp. 114–116, fig. 7c (type locality north of Puerto Rico, 18°15′ N., 67°33′ W., in 50 fathoms, *Silver Bay* station 5192).

ADDITIONAL REFERENCE.

Scorpaena elachys, MOE, and others, 1966, p. 81 (one specimen from west coast of Florida in Florida Board of Conservation collection).

ADDITIONAL MATERIAL. UMML no. 17322 (1, 37) 20°01′ N., 71°39′ W., in 29–24 fathoms, *Silver Bay* station 5149; UMML no. 16165 (5, 19–25) 14°53′ N., 61°06′ W., in 40 fathoms, *Oregon* station 5000; UMML no. 21776 (2, 21–30) 14°03.5′ N., 61°02′ W., in 22–45 fathoms, *Oregon* station 5051; UMML no. 22214 (1, 42) 24°49′ N., 80°39′ W., in 20–25 fathoms, *Gerda* station 753; UMML no. 22204 (1, 33) 9°24.8′ N., 78°12.7′ W., in 28 fathoms, *Pillsbury* station 417.

REMARKS. The species was known from five specimens. The additional specimens plus the types give the following ranges for counts and measurements (UMML no. 16165 not measured). Dorsal fin with 12 spines and 8 (3 specimens) or 9 (11 specimens) soft rays; anal fin with 3 spines and 5 (13) or 6 (1) soft rays; pectoral rays 16 (3, 2 with 17 on right) or 17 (11); head 48–51; depth 37–41; orbit 14–16; snout 11–13; interorbital 5–6; jaw 24–27; predorsal 41–45; pectoral fin 30–36; caudal fin 29–34. Vertebrae 24 in 10 specimens.

The additional specimens have a shorter caudal fin making this a poor character as used in the earlier key (Eschmeyer, 1965a). One specimen lacks nasal spines.

The coloration of the additional specimens is generally pallid as in the types. Most have some faint dusky pigment on the head and body, and some have a dusky smudge on the pectoral fin. The following is a description of the specimen taken by the vessel *Pillsbury* off Colombia. Body generally reddish; upper inside of pectoral a bright yellow; caudal with three bands of red, one at base,

middle, and at end; some yellow on soft dorsal and caudal, mixed with pink specks; anterior half of anal fin dark red, followed by specks in the middle portion, with dark red at distal end; pelvic fin and iris red. Dusky pigment most notably on the pectoral fin, between orbits, and under eye.

Distribution. The species is now known from Puerto Rico, Dominican Republic, Martinique, Saint Lucia, Panama, and Florida. Depths of capture range from about 20 or 25 to 50 fathoms. Most captures have been by use of dredges.

Scorpaena albifimbria Evermann and Marsh.

(See Eschmeyer, 1965a, pp. 116–118, fig. 8, for a detailed treatment.)

Scorpaena albifimbria Evermann and Marsh, 1900, pp. 275–276, fig. 82 (type locality off Culebra Island, Puerto Rico, in 15 fathoms, *Fish Hawk* station 6093).

Additional reference.

Scorpaena albifimbria, Böhlke and Chaplin, 1968, p. 648, illustration (description; Bahamas).

Additional material. The following specimens are from collections by Walter Starck during studies of the fauna of Alligator Reef; all are from Florida, Monroe County, vicinity of Alligator Reef Light in 15–95 feet. UMML no. 20089 (1, 16), UMML no. 18133 (2, 32–39), UMML no. 19251 (, 32), UMML no. 18970 (2, 39–40), and UMML no. 22221 (1, 12).

One uncataloged specimen at TABL of 28 mm. carries the following data: Saint Andrews Island, SW. cove, *Geronimo* Cruise 6, station 190, collected by Richards and Ramsay.

Additional information. Counts for the additional specimens are as follows: dorsal fin XII, 9 (11 specimens) and XII, 8 (1); anal III, 5 (11) and III, 4 (1); pectoral rays 21 + 21 (1), 21 + 20 (1), 20 + 20 (7), 20 + 19 (1), 19 + 19 (2). Vertebrae 24 in 10 specimens. The largest specimen known is only 51 mm. in standard length.

Distribution. *Scorpaena albifimbria* is known from Florida, the Bahamas, Virgin Islands, Haiti, Puerto Rico, Curaçao, and Saint Andrews Island. It is a shallow-water species, occurring in depths from the shore to 17 fathoms.

Scorpaena grandicornis Cuvier.

(See Eschmeyer, 1965a, pp. 118–121, figs. 9a, b, for a detailed treatment.)

Scorpaena grandicornis Cuvier *in* Cuvier and Valenciennes, 1829, p. 309 (type locality Martinique and Puerto Rico).

Additional references.

Scorpaena grandicornis, Diaz, 1893, p. 87 (Cuba). Fowler, 1906, p. 104 (Florida Keys, sea wreck of the Marquesas shallows). Borodin, 1934, p. 117 (listed; Port Antonio, Jamaica). Fowler, 1950, p. 75 (one specimen; Cayo Largo, Cuba). Moe, and others, 1966, p. 81 (Florida specimens in collection of Florida Board of Conservation). Randall, 1968, p. 173, color fig. 195 (brief description; good figure of specimen from the Virgin Islands). Böhlke and Chaplin, 1968, p. 647, illustration (description; Bahamas).

Scorpaena quadricornis, Fowler, 1937b, p. 313 (Haiti; misspelled; name only).
Scorpaena granicornis, Bullis and Thompson, 1965, p. 53 (misspelled; collections by U. S. Fish and Wildlife Service exploratory fishing vessels).

Distinguishing features. The white specks (less than about 0.5 mm. diameter) on a pale or tan background in the axil of the pectoral fin and absence of tympanic spine are diagnostic for this species.

Additional information. Vertebrae 24 in 8 specimens.

Distribution. The species is widespread in the western Atlantic from Florida south to southern Brazil, including Bermuda. It is an inshore species.

Scorpaena plumieri Bloch.

(See Eschmeyer, 1965a, pp. 121–127, figs. 4a, b, c, for a detailed treatment.)
Scorpaena plumieri Bloch, 1789, p. 234 (type locality Martinique).
Central Atlantic references.
Scorpaena scrofina, Günther, 1868, p. 225 (listed; St. Helena). Melliss, 1875, p. 105 (St. Helena; common in shallow water; common name Mail or Rock Gurnard). Cunningham, 1910, p. 115 (St. Helena). Clark, 1913, p. 53 (St. Helena; several specimens; 249–305 mm. total length).
Scorpaena plumieri, Günther, 1881, p. 430 (Ascension). Cadenat and Marchal, 1963, pp. 1287–1288, fig. 37 (specimens from Ascension; comparisons with other species; good figure).
Additional western Atlantic references. (See Eschmeyer, 1965a).
Scorpaena plumieri, Starks, 1913, p. 64 (Natal, Brazil; live color description). Borodin, 1934, p. 117 (listed; Fisher's Island, Florida). Caldwell, 1963, p. 11 (Costa Rica). Bullis and Thompson, 1965, p. 54 (*Oregon* station 2348 and *Silver Bay* stations 438 and 2361). Moe, and others, 1966, p. 81 (specimens in Florida Board of Conservation collection). Randall, 1968, pp. 172–173, color fig. 194 (brief description; good figure). Böhlke and Chaplin, 1968, p. 649, illustration (good description; Bahamas).
Scorpaena rascacio, Diaz, 1893, p. 87 (Cuba; coloration; to 450 mm.).
Scorpaena bufo?, Schomburgk, 1848, p. 667 (Barbados).
Scorpaena brasiliensis, Schomburgk, 1848, p. 667 (misidentified; Barbados).
Scorpaena albofasciata, Fowler, 1950, p. 82, fig. 21 (Old Providence Island, Bahamas; coloration; juvenile).
Scorpaena plumieri plumieri, Cervigon, 1966, pp. 763–765, fig. 322 (description; Venezuela).

Distinguishing features. The white spots or blotches on a black background in the pectoral-fin axil are diagnostic.

Distribution. Currently treated as occurring in the eastern Pacific, western Atlantic, and at Saint Helena and Ascension. In the western Atlantic the species is common from the Atlantic coast of the United States to Rio de Janeiro, Brazil, in depths from the shore to about 30 fathoms.

Additional information. Vertebrae 24 in eight specimens.

Remarks. The species is compared with the closely related *S. laevis* from the eastern Atlantic under the account of *S. laevis*.

Victor Sadowsky forwarded three specimens from Brazil which have the posterior preorbital spine split distally into two close-set spines. This has been observed in specimens from other areas but not with this frequency.

Scorpaena brasiliensis Cuvier.

(See Eschmeyer, 1965a, pp. 127–132, figs. 9c, 10a, for a detailed treatment.)

Scorpaena brasiliensis Cuvier *in* Cuvier and Valenciennes, 1829, p. 305 (type locality Brazil).

Additional references.

Scorpaena brasiliensis, Borodin, 1934, p. 117 (listed; Sombrero Light, Florida). Fowler, 1951, pp. 32–33 (Rio de Janeiro, Brazil). Moe and Martin, 1965, p. 135 (Tampa Bay area, Florida). Bullis and Thompson, 1965, p. 53 (collections by U. S. Fish and Wildlife Service exploratory fishing vessels). Moe, and others, 1966, pp. 79–80 (specimens in Florida Board of Conservation collection). Cervigon, 1966, pp. 762–763, fig. 321 (description; Venezuela). Randall, 1968, p. 173, color fig. 196 (brief description; figure of specimen from the Virgin Islands).

Scorpaena colesi, Nichols and Firth, 1936, p. 1 (off Virginia).

Distinguishing features. The species is distinguished from other species in the Western Atlantic by the combination of about 50–60 scale rows, brown spots usually in pectoral axil and along body to anal fin, usually 2 or 3 large brown spots behind the head, and upper posttemporal spine reduced or absent.

Additional information. Vertebrae 24 in nine specimens.

Distribution. A common inshore species known from Virginia south to southern Brazil, including the Gulf of Mexico. Depths of capture range from the shore to about 50 fathoms.

Scorpaena dispar Longley and Hildebrand.

(See Eschmeyer, 1965a, pp. 132–134, fig. 12b, for a detailed treatment.)

Scorpaena dispar Longley and Hildebrand, 1940, p. 246, fig. 12 (type locality Tortugas, Florida).

Additional references.

Scorpaena dispar, Bullis and Thompson, 1965, p. 53 (collections by U. S. Fish and Wildlife Service exploratory fishing vessels). Cervigon, 1966, pp. 945–946 (compiled; Venezuela).

Distinguishing features. Characterized by presence of 3 preorbital spines, and coloration of black spots on a pallid background, especially on the caudal and pectoral fins.

Additional material. Specimens from the following stations were identified in the collection of the Tropical Atlantic Biological Laboratory; *Silver Bay* stations 1534, 1547, 2360, 3431, 5107, 5708, 5735, and *Oregon* station 3640.

Additional information. Vertebrae 24 in six specimens.

Distribution. The specimens from *Silver Bay* stations 1547 and 5735 extend the range northward to Georgia and South Carolina. Other records include Florida, the Gulf of Mexico, Yucatan, Venezuela, and Brazil, in 20–65 fathoms.

Scorpaena calcarata Goode and Bean.

(See Eschmeyer, 1965a, pp. 134–138, figs. 10b, c, for a detailed treatment.)

Scorpaena calcarata Goode and Bean, 1882, pp. 422–423 (type locality Clear Water Harbor, Florida).

ADDITIONAL REFERENCES.

Scorpaena calcarata, YERGER, 1961, p. 114 (Alligator Harbor, Florida). MOE AND MARTIN, 1965, p. 136 (Tampa Bay area, Florida). BULLIS AND THOMPSON, 1965, p. 53 (collections by U. S. Fish and Wildlife Service exploratory fishing vessels). MOE, and others, 1966, p. 80 (specimens in Florida Board of Conservation collection). CERVIGON, 1966, p. 944 (compiled; Venezuela).

ADDITIONAL MATERIAL. The *Pillsbury* collected specimens from off Panama and Colombia at the following stations: 330 (1 specimen), 333 (2), 362 (2), 365 (5), 366 (4), 367 (1), 368 (1), 370 (2), 371 (1), 378 (3), 379 (7), 380 (3), 411 (1), 430 (2), 433 (5), 435 (5), and 434 (4), in depths from about 20 to 40 fathoms (locality data for the *Pillsbury* stations appeared in Voss, 1966).

DISTINGUISHING FEATURES. Characterized by the absence of an occipital pit (very shallow pit in small specimens), narrow interorbital area, and absence of a supplemental preopercular spine.

ADDITIONAL INFORMATION. Vertebrae 24 in six specimens.

DISTRIBUTION. A coastal species found from the Carolinas to the Gulf of Mexico and south to Brazil.

Scorpaena inermis Cuvier.

(See ESCHMEYER, 1965a, pp. 138–141, figs. 11a, b, for a detailed treatment.)

Scorpaena inermis CUVIER *in* Cuvier and Valenciennes, 1829, pp. 311–312 (type locality Martinique).

ADDITIONAL REFERENCES.

Scorpaena inermis, BULLIS AND THOMPSON, 1965, p. 54 (collections by U. S. Fish and Wildlife Service exploratory fishing vessels). MOE, and others, 1966, p. 81 (specimens in Florida Board of Conservation collection). CERVIGON, 1966, p. 943 (description; Venezuela). BÖHLKE AND CHAPLIN, 1968, p. 645, illustration (description; coloration; good figure; Bahamas).

DISTINGUISHING FEATURES. A small species characterized by the absence of an occipital pit and absence of a supplemental preopercular spine, as in *Scorpaena calcarata*. The small mushroom-like tabs on the cornea (fig. 2c) are diagnostic.

ADDITIONAL MATERIAL. Specimens from the following stations were identified in the collection of the Tropical Atlantic Biological Laboratory: *Silver Bay* stations 2451, 3053, *Oregon* station 3638, and *Geronimo* station 210 (Cruise 6).

ADDITIONAL INFORMATION. Vertebrae 24 in six specimens.

DISTRIBUTION. A clear-water species known from Florida, the Bahamas, Yucatan, the Greater and Lesser Antilles, and the Dutch West Indies. The specimen from *Geronimo* Cruise 6 is from Saint Andrews Island. Depths of Capture range from the shore to about 40 fathoms.

Scorpaena agassizii Goode and Bean.

(See ESCHMEYER, 1965a, pp. 141–144, figs. 11c, 12a, for a detailed treatment.)

Scorpaena agassizii GOODE AND BEAN, 1896, pp. 247–248, pl. 67, fig. 243 (type locality in error [corrected by Eschmeyer, 1965a, to 23°13′ N., 89°10′ W., *Blake* station 36]).

Additional references.

Scorpaena agassizi, Bullis and Thompson, 1965, p. 53 (collections by U. S. Fish and Wildlife Service exploratory fishing vessels). Moe, and others, 1966, p. 70 (specimens in Florida Board of Conservation collection). Cervigon, 1966, pp. 765–766, fig. 323 (description; Venezuela).

Distinguishing features. This species is characterized by a large eye and elongate pectoral fin.

Additional information. Vertebrae 24 in six specimens and 23 in one specimen, the latter also with 8 soft-dorsal rays.

Distribution. An offshore species known from the Atlantic and Gulf coasts of the United States, south to the Guianas in depths from about 25 to 150 fathoms.

Remarks. Occurrence of this species at Bermuda appears to be based on the specimen reported by Barbour (1905, p. 129) which was dredged on the Challenger Bank in 40 fathoms. Mrs. Myvanwy Dick informs me that this specimen is not in the MCZ fish collection. It is possible that *S. agassizii*, which appears to be a continental species, does not occur at Bermuda. At the time of Barbour's writing it was thought that the type locality of *S. agassizii* was the mid-Atlantic east of Cuba, and this may have influenced Barbour's identification.

Scorpaena normani Cadenat.

Scorpaena canariensis (not of Sauvage), Norman, 1935b, pp. 29–30, fig. 11 (in part; specimens from Angola only).

Scorpaena normani Cadenat, 1945, pp. 539–541, fig. 2 (type locality coast of Mauritania; referred Norman's specimens from Angola to this species; description good). Cadenat, 1950, p. 243 (brief description; Sénégal) p. 307 (listed). Cadenat, 1953, p. 1088, fig. 31 (name and figure). Roux, 1957, p. 225 (brief description; area near Point Noire in 80–150 meters). Poll, 1959, pp. 184–187, fig. 67 (numerous specimens from 1°13′ S. to 16°36′ S. in about 60–260 meters; good description and figure). Blache, 1962, p. 74 (listed). Lozano Cabo, 1963, p. 345 (listed; Spanish Sahara-Mauritania). Sanchez, 1966, p. 157, illustration (compiled; Angola).

Material examined. Measurements and counts are based on all or part of the UMML specimens from the following *Pillsbury* stations in the Gulf of Guinea: station 45 (18, 76–124), 59 (2, 112), 232 (3, 97–120), 239 (2, 66–79), 241 (5, 46–72), 254 (2, 99–105), 259 (6, 65–79). Additional specimens from the Gulf of Guinea collected by the *Pillsbury* are from stations 236 (42 specimens), 237 (18), and 245 (42). (Locality data for *Pillsbury* stations are given in Voss, 1966.) The following specimens were collected by Bruce B. Collette (BBC) during Guinean Trawling Survey 1: CAS no. 24271 (1 specimen) Transect 14, station 5, 6°11′ N., 10°54′ W., in 70 meters, BBC 871; CAS no. 24269 (4) Transect 2, station 4, 11°32′ N., 17°11′ W., in 50 meters, BBC 982; CAS no. 24270 (1) Transect 6, station 6, 9°18′ N., 15°32′ W., in

100–108 meters, BBC 943; CAS no. 24268 (2) Transect 9, station 5, 7°50′ N., 14°00′ W., in 70 meters, BBC 919; USNM no. 203796 (2) Transect 13, station 4, 6°40′ N., 11°23′ W., in 50 meters, BBC 882; USNM no. 203794 (2) Transect 16, station 5, 5°24.5′ N., 9°49′ W., in 70 meters, BBC 854; USNM no. 203793 (1) Transect 10, station 6, 7°20′ N., 13°23′ W., in 100 meters, BBC 911; USNM no. 203797 (2) Transect 18, station 5, 4°32′ N., 8°21′20″ W., in 70 meters, BBC 841; USNM no. 203795 (2) Transect 8, station 7, 8°27′ N., 14°23′ W., in 180–200 meters, BBC 930. The following specimens from the Guinean Trawling Survey have been deposited at IFAN, Gorée, Sénégal: Transect 38, station 5 (1 specimen) 6°03.5′ N., 4°16′ W., in 70 meters; Transect 34, station 6 (1) 6°00.5′ N., 1°34′ E., in 100 meters; Transect 42, station 6 (2) 3°50′ N., 6°05′ E., in 100 meters. Additional specimens from the Guinean Trawling Survey were identified and returned to IFAN.

DESCRIPTION. Counts and measurements summarized in tables 1–10; body shape and coloration in figure 6c.

A small, mostly pale species with no occipital pit, chest naked, and with slightly ctenoid scales on the body. Dorsal fin with 12 spines and 9 (rarely 8 or 10) soft rays; penultimate dorsal spine short, about one-third the length of last; spinous dorsal fin characterized by deeply-cleft membranes between 3 or 4 anterior spines allowing anterior dorsal spines to point far forward. Pectoral rays usually 19, rarely 18 or 20, middle pectoral rays doubly branched; pectoral fin reaching to at least second anal spine. Gill rakers number 15–18, usually 16 or 17; upper arch with 5–6, 10–12 on lower arch; all rakers fairly short and spiny. Preorbital bone with 2 spines over maxillary, both point forward. Suborbital ridge usually with 4 spines, 1 on preorbital and 3 on suborbitals, spine on preorbital often absent or sometimes several points on lateral surface of preorbital; some specimens with spines double giving as many as 8 small points on suborbital ridge. Second preopercular spine small. Fourth and fifth preopercular spines well developed. Upper posttemporal spine usually small. Other spines as for the genus. Vertebrae 24 (six specimens). Scales on flanks slightly ctenoid, about 45 vertical scale rows. Pectoral-fin base and chest naked; most scales on head embedded. Occipital pit absent; slight depression present before each parietal spine. Pores at symphysis of lower jaw separate. Interorbital area with 2 well developed ridges which continue into the tympanic spines. Skin appendages on body poorly developed; supraocular tentacle about equal to orbit in small specimens, smaller or absent in larger specimens. Nasal flap and tab associated with posterior preorbital spine large, rest small or absent. Orbit larger than snout, ratio snout divided by orbit 0.7–0.9; orbit into head 2.0–3.6, interorbital width into orbit diameter 1.8–2.4. Second anal spine falling short of third when depressed.

Preserved specimens mostly pallid, with a few dark spots or specks on anterior lateral-line scales, base of dorsal spines, pectoral fin, and above pectoral

fin. Head with some inconspicuous dusky pigment. Smaller specimens with dusky pigment on fins. Color in life bright red with darker spots in position of dusky spots of preserved specimens; pectoral fin spotted with dark-red.

A small to moderate-sized species growing to about 155 mm. standard length.

Comparisons. *Scorpaena normani* belongs with the group of species which have the pectoral-fin base and chest naked. It differs from this group in having no occipital pit; the slight depressions before the parietals suggest that this is secondary. The pores at the symphysis of the lower jaw are separate. *Scorpaena canariensis* and *S. maderensis* similarly have no occipital pit but differ from *S. normani* in having the chest and pectoral-fin base scaled. The deeply-cleft membranes between the anterior dorsal spines are characteristic of specimens of *S. normani*.

Distribution. The species is very common in the Gulf of Guinea. The northern limit of occurrence seems to be about Mauritania, where Cervigon (1960) reported one specimen. The species occurs south of the Gulf of Guinea to Angola. Depths of capture range from about 25 to 125 fathoms. Habitat is mud or sand bottom.

Scorpaena angolensis Norman.

Scorpaena angolensis Norman, 1935b, p. 28, fig. 10 (type locality coast of Angola). Cadenat, 1945, pp. 546–548, fig. 6 (in part; description; specimens from Cape Verde Islands and coast of Mauritania [specimen from Principe Island possibly *S. annobonae*]; coloration of pectoral fin wrongly gives impression of *S. stephanica*). Cadenat, 1950, p. 243, fig. 179 (compiled; comparisons with other species; Sénégal). Roux, 1957, p. 224 (brief description; area around Point Noire in 80–150 meters). Poll, 1959, pp. 184–187, fig. 67 (good description and figure; specimens from West Africa between 1°13′ S. and 16°36′ S., in depths from about 50 to 250 meters). Cervigon, 1960, p. 94 (rare off Mauritania, captured at 20°30′ N., in 35 meters). Blache, 1962, p. 74 (compiled). Lozano Cabo, 1963, p. 345 (listed; Spanish Sahara-Mauritania). Sanchez, 1966, p. 156, fig. (compiled; Angola).

Material examined. Mauritania: IIP uncataloged (1, 137) off Mauritania, 20°30′ N., in 35 meters. Sénégal: IFAN no. 5313 (1, 125) Gorée. Gulf of Guinea: The following were collected by the vessel *Pillsbury*: UMML no. 21772 (2, 59–91) 5°10′–8′ N., 00°25′–28′ W., in 23 fathoms, station 23; UMML no. 21773 (2, 115–118) 5°07′ N., 4°32′–36′ W., in 23–21 fathoms, station 46; UMML no. 15771 (5, 83–101) and UMML no. 21774 (4, 82–115) 4°15′–12′ N., 7°32′–35.5′ W., in 25–42 fathoms, station 65. The following were collected by Bruce B. Collette (BBC) on Guinean Trawling Survey 1: CAS no. 24272 (7, 99–132) Transect 4, station 4, 10°23′ N., 16°25′ W., in 50 meters, BBC 964; CAS no. 24273 (3, 104–137) Transect 6, station 4, 9°24′ N., 15°26′ W., in 50 meters, BBC 946; USNM no. 203798 (2, 75–90) Transect 2, station 4, 11°32′ N., 17°11′ W., in 50 meters, BBC 982; USNM no. 203799 (2, 105–117) Transect 7, station 5, 9°03′ N., 14°49′ W., in 70–72 meters, BBC

936. Additional specimens from the Guinean Trawling Survey have been identified and deposited at IFAN, Gorée, Sénégal.

DESCRIPTION. Counts and measurements summarized in tables 1–10; body shape and coloration in figure 8b.

A moderate-sized species with a spot on the spinous dorsal fin, occipital pit present, pores at symphysis of lower jaw united, chest and pectoral-fin base naked, and slightly ctenoid scales on the body. Dorsal fin normally with 12 spines and 9 soft rays. Pectoral rays 17–19, usually 18, rays 2–8 to 10 branched, compound branching in largest specimens; pectoral fin reaches to about over first anal spine. Gill rakers including rudiments 14–17, upper arch with 4–6, lower 9–12, usually 5 + 10 or 11. Preorbital bone with 2 spines over maxillary in small specimens and 3 in the larger specimens, middle preorbital spine small and at base of first (absent in juveniles); first points mostly forward, third points down. Suborbital ridge almost always with no spines on preorbital bone and 3 spines on the suborbital bones, the first and second below ridges and third shortest. Second preopercular spine normal. Upper posttemporal spine present. Other spines as for the genus. Vertebrae 24 (five specimens). Scales on flanks ctenoid, about 40–46 vertical scale rows; head, pectoral-fin base, and chest naked. Occipital pit deep. Pores at symphysis of lower jaw united. Interorbital area deep, with two ridges poorly developed. Skin appendages well developed; supraocular tentacle usually less than ½ orbit diameter, larger in small specimens. Orbit diameter about equal to snout length or slightly larger than snout in small specimens, ratio snout divided by orbit 0.7–1.0; orbit into head 3.2 (smaller specimens) to 4.0; interorbital width into orbit diameter 1.8–2.6 (larger specimens tend to have lower values). Second anal spine usually falling slightly beyond third when depressed.

Coloration of preserved specimens as in figure 8b. Smaller specimens with more dark pigment on pectoral, pelvic, and anal fins. Spot on dorsal fin usually between spines 6 and 9, sometimes more restricted. Pigment of spots on caudal mostly confined to rays.

COMPARISONS. *Scorpaena angolensis* belongs in the group having the pectoral-fin base and chest naked. Like *S. loppei*, *S. annobonae*, and *S. azorica*, the pores at the symphysis of the lower jaw are united. These four species are separated in the key and mentioned under the accounts of *S. loppei*, *S. annobonae*, and *S. azorica*.

DISTRIBUTION. The species is known from Mauritania to Angola and is especially common in the Gulf of Guinea. Cadenat (1945, p. 547) records 3 specimens from the Cape Verde Islands. The species is considered mostly coastal in habitat, living on mud-sand bottom in depths from about 20 to 125 fathoms.

REMARKS. Cadenat's specimen from the island of Principe is tentatively referred to *S. annobonae*.

Scorpaena stephanica Cadenat.[3]

Scorpaena scrofa, Cadenat, 1937, p. 497 (specimens from Sénégal and Guinea, in 100–265 meters).

Scorpaena stephanica Cadenat, 1945, pp. 550–552, fig. 8 (type locality Mauritania; additional specimens from Sénégal and Guinea). Cadenat, 1950, p. 307 (listed). Poll, 1959, pp. 188–191, fig. 68 (description; specimens from West Africa between 9°31.5′ N. to 13°05′ S., in depths from about 50–200 meters). Cervigon, 1960, pp. 93–94 (two specimens from off Mauritania at 21°50′ N., in 90 meters). Blache, 1962, p. 74 (compiled). Lozano Cabo, 1963, p. 345 (listed; Spanish Sahara-Mauritania). Sanchez, 1966, p. 158 (compiled; Angola).

Scorpaena gaillardae Roux, 1954, pp. 470–472 (type locality French Equitorial Africa [probably near Point Noire]; one specimen 350 mm. total length). Roux, 1957, pp. 225–228, 2 figs. on p. 368 (description; 150 meters, near Point Noire). Blache, 1962, p. 74 (compiled).

Material examined. UMML no. 15246 (1, 80) 4°23′–22′ N., 7°06.5′–08.5′ W., in 37 fathoms, *Pillsbury* station 64; UMML no. 22837 (3, 26–148) and UMML no. 16750 (2, 69–144) 4°23′–24′ N., 8°05.5′–07.5′ W., in 38 fathoms, *Pillsbury* station 68. The following specimens were collected by Bruce B. Collette (BBC) during Guinean Trawling Survey 1: CAS no. 24277 (5, 146–232) Transect 1, station 5, 12°03′ N., 17°14′ W., in 100 meters, BBC 994; USNM no. 203803 (2, 98–225) Transect 1, station 6, 12°06′ N., 17°14′ W., in 100 meters, BBC 995; USNM no. 203801 (4, 60–92) Transect 2, station 4, 11°32′ N., 17°11′ W., in 50 meters, BBC 982; CAS no. 24274 (1, 84) Transect 6, station 6, 9°18′ N., 15°32′ W., in 100–108 meters, BBC 943; USNM no. 203804 (2, 186–215) Transect 8, station 6, 8°28′ N., 14°21′ W., in 100 meters, BBC 929; USNM no. 203800 (4, 88–170) Transect 9, station 5, 7°50′ N., 14°00′ W., in 70 meters, BBC 919; CAS no. 24276 (5, 80–166) Transect 10, station 6, 7°20′ N., 13°23′ W., in 100 meters, BBC 911; CAS no. 24275 (1, 69) Transect 13, station 4, 6°40′ N,. 11°23′ W., in 50 meters, BBC 882; USNM no. 203805 (2, 229–230) Transect 17, station 6, 4°40′ N., 9°11′ W., in 100 meters, BBC 849; USNM no. 203802 (1, 166) Transect 18, station 5, 4°32′ N., 8°21′20″ W., in 70 meters, BBC 841. Additional specimens from the Guinean Trawling Survey have been deposited at IFAN, Gorée, Sénégal.

Description. Counts and measurements summarized in tables 1–10; body shape and coloration in figure 10b.

A large species with a spot on the spinous dorsal fin, occipital pit present, chest and pectoral-fin base naked, ctenoid scales on the body, and pores at symphysis of lower jaw separate. Dorsal fin normally with 12 spines and 9 soft rays. Pectoral rays 17–19, usually 18, rays 2–7 to 10 branched in specimens over about 60 mm. standard length; compound branching in larger specimens; pectoral fin usually reaching first anal spine. Gill rakers including rudiments usually 15–18, upper arch 4–6, lower arch 10–12, all short. Lower rakers

[3] See Addendum.

often as groups of spinules. Preorbital bone with 2 spines over maxillary in small specimens (to about 65 mm.) and 3 spines in larger specimens; middle spine small (absent in juveniles) and at base of first; first points forward, third points forward to down, middle spine variable in direction. Suborbital ridge usually with 3 or 4 spinous points, first on preorbital (sometimes absent). Second preopercular spine normal. Upper posttemporal spine present. Other spines as for the genus. Vertebrae 24 (eight specimens). Scales on sides ctenoid, 43–48 vertical scale rows. Head, pectoral-fin base, and chest naked. Occipital pit moderate to fairly shallow. Interorbital area with 2 ridges which end at the front of the occipital pit. Pores at symphysis of lower jaw separate. Skin appendages usually well developed. Supraocular tentacle usually smaller than orbit. Tentacle at posterior preorbital spine large. Small tentacles on maxillary. Orbit diameter larger than snout in small specimens to smaller than snout in larger specimens, ratio snout divided by orbit 0.8–1.2; orbit into head 3.1–4.4 (larger specimens tend to have higher values); interorbital width into orbit diameter 1.6–2.6. Second anal spine when depressed about equal to third in smaller specimens or shorter than third in larger specimens.

Coloration as in figure 10b. Smaller specimens with 5 saddle-shaped dark areas along back, one at beginning of dorsal fin, under middle dorsal spines, under posterior dorsal spines, below soft dorsal fin, and on caudal peduncle. In larger specimens these dark areas more diffuse, often poorly marked. Caudal fin, dorsal fin, and pectoral fins with dusky spots. Pelvic fins dusky in small specimens. Anal fin with poorly defined dusky spots in smaller specimens to clear in large specimens. Dorsal fin with black patch between about spines 6–7 to 10–11, sometimes restricted.

Comparisons. *Scorpaena stephanica* belongs with the group of species with the pectoral-fin base and chest naked. The species resembles *S. scrofa* in coloration, but lacks the tentacles on the lower jaw as in *S. scrofa*. Also, the species somewhat resembles *S. angolensis* but is most easily separated from it by having separate pores at the symphysis of the lower jaw. It is probably most closely related to *S. elongata*.

Distribution. The species is known from coastal waters from Mauritania to Angola in depths from about 25 to 110 fathoms.

Remarks. The figures shown by Roux (1957, p. 368) leave little doubt that *S. gaillardae* is a junior synonym of *S. stephanica*.

Scorpaena elongata Cadenat.

Scorpaena elongata Cadenat, 1945, pp. 552–554, fig. 9 (type locality Cape Blanc, Mauritania; 5 specimens from about 100 meters, good description). Cadenat, 1950, pp. 242–243, fig. 180 (compiled) p. 307 (listed). Boutiere, 1958, p. 12, and following, pls. 2–3 (coast of Morocco in about 200–300 meters; specimens from 12–46 cm. total length; good photographs; notes on biology). Boutiere, 1959, pp. 406–407 (Banyuls, France; first from Mediterranean). Cervigon, 1960, p. 94 (common off Mauritania). Maurin,

1962, pp. 193–4, 197, 205–6 (collections in Mediterranean; depths of capture). Lozano Cabo, 1963, pp. 335, 345 (listed; Spanish Sahara—Mauritania).

Material examined. IIP uncataloged (2, 159–210) coast of Mauritania at 22° N., in 180 meters; CAS no. 24278 (2, 217–219) and USNM no. 204095 (2, 145–240) Transect 8, station 6, 8°28′ N., 14°21′ W., in 100 meters, BBC 929; UMML no. 23308 (2, 224–255) Transect 2, station 7, 11°25′ N., 17°21′ W., in 200 meters, BBC 985.

Description. Counts and measurements summarized in tables 1–10; body shape and coloration in figure 10a.

A moderate to large species with no dark spot on the spinous dorsal fin, occipital pit present, chest and pectoral-fin base naked, ctenoid scales on sides, and pores at symphysis of lower jaw separate. Dorsal fin normally with 12 spines and 9 soft rays. Pectoral rays 18–20, usually 19, rays 2–8 to 12 branched in specimens over about 150 mm. standard length; compound branching in large specimens; pectoral fin usually not reaching over first anal spine. Gill rakers including rudiments 13–16 in available specimens, 4–5 plus 9–11. Preorbital bone usually with 2 spines over maxillary; sometimes a small spine at base of anterior spine. Suborbital ridge with 3 or 4 spinous points, anterior one (on preorbital) sometimes absent. Upper posttemporal spine present. Second preopercular spine normal. Other spines as for the genus. Vertebrae 24 (two specimens). Scales on sides ctenoid, vertical scale rows about 45–50. Most of head naked; pectoral-fin base and chest naked. Occipital pit fairly shallow. Interorbital area with 2 ridges which end at the front of the occipital pit. Pores at symphysis of lower jaw small and separate. Skin appendages fairly well developed. Supraocular tentacle small, large flap associated with posterior preorbital spine, large flap at fourth and fifth preopercular spines. Orbit diameter larger than snout in small specimens to smaller than snout in large specimens, ratio snout divided by orbit 0.9–1.3; orbit into head 3.9–4.4, larger specimens with higher values; interorbital width into orbit diameter 1.5–2.1.

Coloration as in figure 10a. Soft-dorsal, anal, caudal, and pectoral fins usually with faint large spots or blotches of brown. Sometimes posterior part of spinous dorsal fin with brownish pigment, but not in a conspicuous spot. Most of the head brownish. Pigment on body usually concentrated in several large brownish blotches along the sides.

A fairly large species, largest available 255 mm. in standard length. Boutiere (1958, p. 78) had specimens to 460 mm. total length.

Comparisons. *Scorpaena elongata* belongs with the group of species with the pectoral-fin base and chest naked, and with the group of species having the pores at the symphysis of the lower jaw separate. The species is probably closest to *S. stephanica* and *S. scrofa*; *S. elongata* differs from *S. scrofa* in lacking the cutaneous tabs on the lower jaw and differs from *S. stephanica* in

having no black spot on the spinous dorsal fin, a shorter pectoral fin, and higher average number of pectoral rays.

DISTRIBUTION. The species is known from the Mediterranean Sea (Boutiere, 1959, and Maurin, 1962), and is common off Morocco and Mauritania (Boutiere, 1958, and Cervigon, 1960). The southernmost capture appears to be the specimen examined from 8°28′ N. Depths of capture range from about 55 to 225 fathoms. The species appears to be an offshore continental species living on soft bottom.

Scorpaena scrofa Linnaeus.

(A partial synonymy pertinent to the scope of the study. References without information in parentheses were not seen. Many references to this species are probably based on misidentifications or mixed collections.)

Scorpaena scrofa LINNAEUS, 1758, p. 266 (type locality Mediterranean Sea). VALENCIENNES, 1835, p. 20. VALENCIENNES, 1836, p. 461. LOWE, 1840, p. 36 (Madeira; comparisons with *S. ustulata*). LOWE, 1843, p. 105, pl. 16 (Madeira; description). BONAPARTE, 1846, p. 62 (synonymy; mostly compiled; wrongly includes *S. notata*). GÜNTHER, 1860, pp. 108–110 (synonymy; brief description; specimens in British Museum). TROSCHEL, 1866, p. 206. STEINDACHNER, 1865, p. 400 (listed; Santa Cruz, Teneriffe). STEINDACHNER, 1867, pp. 75–77. CAPELLO, 1867, p. 257 (rare; Portugal). GÜNTHER, 1880, p. 3 (listed; St. Vincent, Cape Verde Islands). MOREAU, 1881, pp. 310–315, fig. 116 (synonymy; description; distribution; *S. lutea* in synonymy). ROCHEBRUNE, 1883, p. 85. MEEK AND NEWLAND, 1885, pp. 394, 398 (brief synonymy; description in key; specimens from Venice). ?DAY, 1887, p. 342 (specimen from south coast of England; range). HILGENDORF,1888, p. 207. VINCIGUERRA, 1890, p. 467. DÖDERLEIN, 1891, pp. 276–278 (lengthy synonymy; common names; *S. lutea* as variety; distribution). CARUS, 1893, p. 639. VIEIRA, 1894, p. 10. NOBRE, 1895, p. 230. VIEIRA, 1898, p. 31. PIETSCHMANN, 1906, p. 142. HOLT AND BYRNE, 1908, pp. 26–28, fig. (description compiled; figure from Lowe; unknown from British and Irish waters). SEABRA, 1911, p. 150. MURRAY AND HJORT, 1912, p. 407, fig. 298 (Cape Blanco in 39–77 meters). ROULE, 1919, p. 59 (southwest of St. Lucia, Cape Verde, in 17 meters). KOEFORD, 1927, p. 130 (brief description; *Michael Sars* stations 37 and 38 in 39 and 77 meters). NOBRE, 1928, p. 44, figs. 21–22. BORODIN, 1930, p. 58 (listed; Naples). GREGORY, 1933, p. 325, fig. 203 (osteology; after Allis, 1909). NOBRE, 1935, pp. 100–102, figs. 41–42 (synonymy of records from Portugal; description; distribution off Portugal). ?NORMAN, 1935a, p. 614 (specimens off England [locality seems unlikely]). FOWLER, 1936, pp. 922–924 (synonymy; description mostly compiled). VERRIER AND ESCHER-DESRIVIERES, 1937, p. 126, and following (vision). CADENAT, 1945, pp. 548–550, fig. 7 (good description; comparisons). SPARTA, 1941b, pp. 203–205 (description of eggs and larvae). ?IRVINE, 1947, p. 203 (brief description; Ghana). CADENAT, 1950, p. 243 (distinguishing features; Sénégal) p. 307 (listed). CADENAT, 1953, p. 1057 (listed; West Africa; 13 specimens from 100 meters) p. 1088, fig. 32 (characterization; figure not showing tentacles on lower jaw; [*S. scrofa* variety probably *S. stephanica*]). BEN-TUVIA, 1953, p. 28 (listed; Israel). COLLINS, 1954, p. 31 (listed; Azores). SMITH, 1957a, pp. 51–52 (*S. natalensis* in synonymy; description; compared with specimens from Madeira and the Mediterranean Sea; Ascension Island in error; specimens from Algoa Bay to Durban in 30–50 fathoms). BOUTIERE, 1958, p. 12, and following (Morocco; life history notes). MAURIN, 1962, p. 176, and following (collections in Mediterranean). LOZANO CABO, 1963, p. 345 (listed; Spanish Sahara-Mauritania).

Scorpaena barbata (not of Grey), Lacépède, 1802, p. 259.
Scorpaena lutea Risso, 1810, p. 190 (type locality Nice).
?*Scorpaena natalensis* Regan, 1906, p. 5, pl. 5 (type locality coast of Natal, South Africa).

Nomenclatural remarks. Pre-Linnaean names and additional references to this species may be found in Döderlein, 1891.

I am following Smith (1957a, pp. 51–52) in including *S. natalensis* in the synonymy of *S. scrofa*. I have no specimens from off South Africa. Smith could find no differences between specimens from South Africa and ones from the Mediterranean Sea and Madeira. *Pillsbury* and *Geronimo* operations in the Gulf of Guinea took no specimens of *S. scrofa*, and the Guinean Trawling Survey took none east of 17°14′ W., nor does Poll (1959) report capture of specimens off West Africa. Irvine's (1947, p. 203) record from Ghana is probably based on specimens of *S. angolensis*. There appears, therefore, to be an interruption in the distribution, the specimens collected between the Cape and Natal forming an isolated population worthy of more study. In the light of additional material, Smith's suggestion that *S. angolensis* Norman was based on juvenile specimens of *S. scrofa* is incorrect. Other references to *S. natalensis* are given by Smith.

Material examined. Mediterranean Sea: USNM no. 48302 (1, 135) and USNM no. 48306 (1, 96) Bay of Naples, collected by Seth E. Meek; USNM no. 124430 (1, 211) Italy, presumed; AMNH no. 2955 (1, 152) Italy, market at Naples; AMNH no. 20555 (1, about 190) Italy, Gulf of Genoa, E. Tortonese, 1956; ANSP no. 12164–12166 (3) and USNM no. 2231 (1, 192) Mediterranean, C. L. Bonaparte collection. Madeira: ANSP no. 95589 (1, 156) Funchal market. Sénégal—Portugues Guinea: USNM uncataloged (2, 135–145) 12°06′ N., 17°14′ W., in 100 meters, GTS I, Transect 1, station 6, BBC 995.

Description. Counts and measurements summarized in tables 1–10; body shape and coloration in figure 9b, c.

A moderate to large species with a dark spot frequently present on spinous dorsal fin, occipital pit present, chest and pectoral-fin base naked, ctenoid scales on sides, pores at symphysis of lower jaw separate, and tentacles present on lower jaw under head. Dorsal fin normally with 12 spines and 9 soft rays. Pectoral rays 18–20, usually 19, rays 2–7 to 12 branched in specimens over about 100 mm. in standard length (Boutiere, (1953, p. 72) gives 14 branched rays in 1 specimen); compound branching in larger specimens; pectoral fin usually falling short of first anal spine. Gill rakers 14–17 including rudiments, 4–5 on upper arch, 10–12 on lower arch. Preorbital bone with 3–4 spinous points over maxillary in adults, second (at base of first) sometimes absent (juveniles probably with only 2 spines over maxillary). Suborbital ridge with 2–4 spinous points, first (on preorbital) frequently absent, third frequently as lump. Upper posttemporal spine present. Second preopercular spine normal. Other spines as for the genus. Vertebrae 24 (two specimens). Scales on sides

ctenoid, vertical scale rows number in middle forties. Most of head naked, or with embedded cycloid scales; pectoral-fin base and chest naked. Occipital pit moderate. Interorbital area with 2 ridges which end at the bases of the tympanic spines. Pores at symphysis of lower jaw small and separate. Supraocular tentacle usually small or absent. Numerous tentacles present on lower jaw, large skin flap associated with posterior preorbital spine, and flaps on fourth and fifth preopercle spines. (The following based on 7 specimens 96–211 mm. standard length.) Orbit smaller than snout, ratio snout divided by orbit 1.2–1.4; orbit into head 4.4–5.1, larger specimens with higher values; interorbital width into orbit diameter 1.5–1.7.

Coloration variable. Dorsal, caudal, anal, and pectoral fins blotched or mottled with brown. Distal part of pelvic fin usually dusky. Head and body brownish; smaller specimens with brown pigment in 5 poorly defined saddle-shaped patches along dorsal fin (similar to *S. stephanica*). Dorsal fin with black spot frequently present between spines 6–11 (fig. 9b), but usually more restricted or absent (fig. 9c).

A fairly large species, largest available specimen 211 mm. in standard length. Boutiere (1958, p. 78) reports specimens to 490 mm. total length.

Comparisons. *Scorpaena scrofa* belongs with the group of species which have the chest and pectoral-fin base naked, and pores at the symphysis of the lower jaw separate. The species is compared with *S. elongata* and *S. stephanica* under the account of *S. elongata*. *Scorpaena scrofa*, among those with ctenoid scales, is unique in having tentacles on the lower jaw; *S. scrofa* also usually has more preorbital spines (4 normally) versus 3 (rarely 4) or fewer.

Distribution. The species occurs from England [questionable], throughout the Mediterranean, at Madeira, Cape Verde Islands, Canaries, and off Morocco south to about Sénégal. One record from Ghana (Irvine, 1947) probably represents *S. angolensis*. The most southern capture appears to be the specimens taken by the Guinean Trawling Survey at 12°06′ N. (see Nomenclatural remarks). Depths of capture range from near shore to about 150 meters. Boutiere (1958, pp. 58–59) reports the species to be common off Morocco in rock, sand, and coral areas.

Remarks. Although other species are fairly constant in presence or absence of a dark spot on the spinous dorsal, *S. scrofa* is more variable in this character, often lacking the spot. This species is the only one of the group with a naked chest that has tentacles on the lower jaw. These tentacles were found in all specimens. Cadenat (1953, p. 1057) lists a variety of *S. scrofa* from 100 meters which is probably *S. stephanica*.

Scorpaena laevis Troschel.

Scorpaena laevis Troschel, 1866, p. 206 (type locality Cape Verde Islands). Guimarães, 1884, p. 18 (St. Jago, Cape Verde Islands). Osorio, 1890, p. 278 (listed; Cape Verde

Islands). Osorio, 1894, p. 182 (listed; São Tome). Osorio, 1898, p. 196 (listed; Cape Verde and Angola). Fowler, 1936, pp. 927, 1307 (compiled). Irvine, 1947, p. 204 (brief description; Ghana). Roux, 1957, pp. 224–225 (brief description; one caught in rocks at Point Noire). Blache, 1962, p. 74 (compiled). Cadenat and Marchal, 1963, p. 1289 (placed *S. senegalensis* in synonymy of *S. laevis*).

Scorpaena plumieri, Capello, 1871, p. 200 (specimens from Mossamedes, Cape Verde Islands, and São Tome). Osorio, 1906, p. 157. Fowler, 1936, pp. 924–925 (USNM specimens from Madeira and Azores; description from American specimens). Collins, 1954, p. 30 (compiled from Fowler; listed; Azores). Lozano Cabo, 1961, p. 149 (compiled). Blache, 1962, p. 74 (compiled; doubtful in eastern Atlantic).

?*Scorpaena grandicornis*, Capello, 1871, p. 200 (São Tome). Fowler, 1936, pp. 926–927 (in part; synonymy; description of *S. grandicornis* from Puerto Rican specimens). Lozano Cabo, 1961, p. 147 (compiled). Blache, 1962, p. 74 (compiled; doubtful in eastern Atlantic).

Scorpaena senegalensis Steindachner, 1881, p. 21, pl. 4 (type locality Rufisque, Sénégal). Rochebrune, 1883, p. 63 (compiled). Osorio, 1898, p. 196 (listed; São Tome). Osorio, 1909, p. 65 (compiled). Fowler, 1919, pp. 214–215 (description; comparisons; Porto Grande, Cape Verde Islands). Fowler, 1936, pp. 925–926, 1307 (synonymy; description of specimens from the Cape Verde Islands). Irvine, 1947, p. 204 (brief description; Ghana). Cadenat, 1950, p. 243, fig. 178 (brief description; length to 35 cm.; Sénégal). Cervigon, 1960, p. 94, fig. 55 (Mauritania; from 19° N. and 19°30′ N.; brief description; figure good). Lozano Cabo, 1961, p. 147 (compiled). Blache, 1962, p. 74 (compiled).

Material examined. Annobón Island: UMML no. 22218 (3, 44–61) shore station, 1°24′ S., 5°37′ E., *Pillsbury* station 273; UMML no. 22217 (1, 200) purchased from local fisherman, *Pillsbury* station 276. Fernando Póo: UMML no. 22836 (3, 28–50) shore station, 3°45′ N., 8°48′ E., *Pillsbury* station 258. Coastal Gulf of Guinea: USNM uncataloged (1, 208) Tema Nungua, Ghana, Gilbert W. Bane no. 882; USNM uncataloged (1, 177) Takorad, Ghana, Gilbert W. Bane no. 789; USNM uncataloged (2, 120–216) GTS 1, Transect 10, station 2, 7°33.5′ N., 13°19′W., in 30 meters, BBC 906; USNM uncataloged (1, 197) GTS 1, Transect 13, station 3, 6°41′ N., 11°23′ W., in 40 meters, BBC 881. The following from GTS 1 have been sent to Gorée: Transect 31, station 2n (1, 145) 5°18′ N., 0°24′ W., in 36 meters. Transect 32, station 1.2 (1, 220) 5°40′ N., 0°13′ E., in 22 meters.

Description. Counts and measurements summarized in tables 1–10; body shape and coloration in figure 11a, b.

A moderate to large species with cycloid scales and chest and pectoral-fin base scaled. Dorsal fin normally with 12 spines and 9 soft rays. Pectoral rays 19–20, rarely 18, rays 2–5 branched in a 60-mm. specimen and rays 2–12 to 15 branched in 200-mm. specimens; compound branching in larger specimens; pectoral fin reaching to about first anal spine as maximum. Preorbital bone with 2 spines over maxillary in juveniles and 3 in adults; sometimes double spine gives count of 4. Suborbital ridge with 0 to several points on preorbital and usually 3 points on suborbitals. Upper posttemporal spine present. Second preopercular spine normal. Other spines as for the genus. Vertebrae 24 (six

specimens). All scales cycloid. Vertical scale rows about 40–45. Pectoral-fin base, cheek, and chest scaled, these scales mostly embedded. Occipital pit deep. Interorbital area wide and deep, with poorly developed ridges. Pores at symphysis of lower jaw separate. Supraocular tentacle variable, some specimens with tentacle longer than orbit diameter; other tentacles also variable but usually well developed; tentacles are usually present under the head at the isthmus area and on the lower jaw. Orbit about equal to or smaller than the snout, ratio snout divided by orbit 1.0–1.3; orbit into head 4.1 (smaller specimens) to 5.2; interorbital width into orbit diameter 1.1–1.4.

Coloration variable, adults and juveniles differing markedly. Pigmentation of juveniles as in figure 11b. In juveniles, the axil of the pectoral fin is dark brown to black with some white specks or blotches (the *S. plumieri* pattern, see "Comparisons"). The brown blotches form on the inside of the pectoral fin at about 50 or 60 mm. standard length. Adults have the inside of the pectoral fin with large brown spots. The pigment on the body as shown in figure 11b is typical for specimens from about 40–80 mm., with the caudal peduncle being palest. (Smaller specimens possibly are almost entirely dark except for the white caudal peduncle as in *S. plumieri*.) Larger specimens are variable in coloration and this is largely related to habitat; they may be mostly pallid, (fig. 11a) as the Annobón specimen, to mainly brown as those from coastal areas. The dorsal fin is variously mottled with brown, sometimes a black spot is present at about the sixth to eighth dorsal spines.

Comparisons. *Scorpaena laevis* appears to have no close relative in the eastern Atlantic but is very closely related to *S. plumieri* from Ascension, St. Helena, the western Atlantic, and eastern Pacific. The coloration of juveniles is similar and no doubt led to the misidentification by Capello (1871) of eastern Atlantic specimens. The pigmentation of the body of adults is similar and shows about the same variation in intensity as related to habitat. As in *S. plumieri*, *S. laevis* appears to be common in rocky island areas and also occurs offshore in level-bottom coastal areas. One major difference exists between the two species, the pigmentation of the pectoral fin of adults (see Cadenat and Marchal, 1963, figs. 37–38). *Scorpaena plumieri* has the axil and lower inside of the pectoral fin black with large white spots or blotches, while adult specimens of *S. laevis* have the inside of the pectoral fin with large brown spots on a pallid background. It is assumed that the behavior involving the rolling forward of the pectoral fins, displaying the vivid coloration on the inside of the pectoral, is of much biological importance. This type of display has been shown for *S. plumieri* by Breder (1963, pp. 698–699, figs. 1–2). Compared to western Atlantic specimens of *S. plumieri* (Eschmeyer, 1965, tables 3–13), *S. laevis* is similar to *S. plumieri* in most measurements but appears to average shorter in some measurements associated with the head (jaw, predorsal, etc.). In a world treatment, subgeneric consideration should be given to the group of

species, including *S. plumieri* and *S. laevis*, which have high-set orbits, wide interorbitals, and the characteristic pit in front of the eye formed by an ascending process from the preorbital attaching to the prefrontal. The genus *Scorpaenopsis*, differing from *Scorpaena* in having no palatine teeth, appears superficially to be closely related to the *S. plumieri* group.

Distribution. *Scorpaena laevis* is known from the Azores, Madeira, Cape Verde Islands, Mauritania, Sénégal, and the Gulf of Guinea south to Point Noire. It appears to be common about the islands of São Tome, Annobón, and Fernando Póo in the Gulf of Guinea. The species is unknown from the Mediterranean. The most common habitat appears to be rocky areas in shallow water, but the species was collected fairly regularly in the Gulf of Guinea in offshore level-bottom areas in depths to about 25 fathoms. Boutiere (1958) reported no captures off Morocco.

Scorpaena loppei Cadenat.

Scorpaena loppei Cadenat, 1945, pp. 541–543, fig. 3 (type locality Gulf of Gascogne, in 200 meters; good description based on 33 specimens, 5 from off Rio de Oro). Boutiere, 1958, p. 12 and following (coast of Morocco in 80–100 meters; life-history notes). Boutiere, 1959, pp. 405–407 (region of Banyals, Mediterranean, in 70–120 meters).

Material examined. USNM no. 201148 (1, 55) Mediterranean, Bay of Naples, collected by S. E. Meek; ANSP no. 12177 (1, 59) Mediterranean, C. L. Bonaparte no. 89, J. B. Wilson.

Description. Counts and measurements summarized in tables 1–10. Crest on maxillary shown in figure 2e; body shape and coloration in figure 7c. (Information from Boutiere, 1958, is included.)

A small species with a dark spot on the spinous dorsal fin, occipital pit present, chest and pectoral-fin base naked, ctenoid scales on the side, pores at symphysis of lower jaw united, and a characteristic crest on the maxillary. Dorsal fin normally with 12 spines and 9 soft rays (last double). Pectoral fin with 18 rays (one specimen with 17 on 1 side, occasional specimens with 17 or 19 expected), rays 2 through 7–9 branched in larger specimens. Gill rakers including rudiments 14–16 in available specimens, 5 on upper arch, 9–11 on lower arch (Boutiere [p. 74] gives 7 or 8 on lower arch, not including rudiments). Preorbital bone with 2 spines over maxillary, first is very blunt, second is long and curved to rear (Cadenat, 1945, p. 543, states that there is only 1 preorbital spine; this undoubtedly refers to the posterior one). Suborbital ridge with 4 spinous points, first on preorbital. Upper posttemporal spine present. Second preopercular spine normal. Other spines as for the genus. Vertebrae 24 (one specimen). Scales on sides weakly ctenoid; vertical scale rows about 35–40. Chest, pectoral-fin base, and head naked. Occipital pit present. Interorbital area with 2 ridges. Pores at symphysis of lower jaw united. Tentacles on head and body moderate to poorly developed. Length of supraocular tentacle less than

orbit diameter. The following based on 2 specimens, 55–59 mm. in standard length: orbit slightly larger than snout, ratio snout divided by orbit 0.8–0.85; orbit into head 3.4–3.6; interorbital width into orbit diameter 1.9–2.1.

Available specimens much faded. Trace of dark spot on spinous dorsal fin between about spines 6–10, at distal half of fin. Dark pigment on body more concentrated in patches below spinous dorsal fin, between soft dorsal fin and anal fin, and on the posterior part of the caudal peduncle. Fins with traces of dusky pigment.

Comparisons. This species is characterized by the presence of a crest on the maxillary (fig. 2e). The species appears to be closely related to *S. annobonae* from Annobon Island, but *S. annobonae* lacks the crest on the maxillary. *Scorpaena annobonae* may also differ by normally having 10 rather than 9 soft dorsal rays (last ray double). These two species, plus *S. azorica* and *S. angolensis*, agree in having the pores at the symphysis of the lower jaw united.

Distribution. The species was described from specimens collected in the Gulf of Gascogne in the Bay of Biscay and from specimens collected off the Spanish Sahara (Rio de Oro), both collections from about 200 meters. Boutiere (1958) reported eight specimens from off Morocco in about 100 meters, and in 1959 reported the species from the region of Banyuls in the Mediterranean at a depth of 120 meters. Of the two specimens I have examined from the Mediterranean, one extends the range to the Bay of Naples.

Scorpaena annobonae Eschmeyer, new species.

(No literature applies to this species with the possible exception of the specimen from the Island of Principe identified as *S. angolensis* by Cadenat (1945, p. 547).)

Material examined. Holotype: UMML no. 22219 (1, 44) Annobon Island, 1°24′ N., 5°38′ E., in 5–26 fathoms, dredge, *Pillsbury* station 275 (haul 2).

Description. Counts and measurements summarized in tables 1–10; body shape and coloration in figure 8c.

Only a single small specimen known. A dark spot on the spinous dorsal fin, occipital pit present, chest and pectoral-fin base naked, ctenoid scales on the sides, and pores at symphysis of lower jaw united. Dorsal fin with 12 spines and 10 soft rays (last split). Pectoral fin with 18 rays, rays 2–7 branched, compound branching of some rays; pectoral fin long, reaching to over third anal spine. Gill rakers short, 5 + 9 including rudiments. First preorbital spine truncated, second longer and curved to rear. Suborbital ridge with 3 spines, only ridges on preorbital bone. Upper posttemporal spine present. Second preopercular spine normal. Other spines as for the genus. Vertebrae 24. Scales on sides weakly ctenoid, about 36–38 vertical scale rows. Chest, pectoral-fin base, and head naked. Interorbital area with 2 poorly developed ridges. Pores at symphysis of lower jaw united into one very large pore. Tentacles on head and body moderate; supraocular tentacle about two-thirds to about equal to orbit

diameter; other skin appendages at preocular spine, posterior preorbital spine, under suborbital ridge, at anterior nostril, on eye, lower preopercular spines, on a few scales behind the head, and on some lateral-line scales. Orbit about equal to snout, ratio snout divided by orbit 0.97; head divided by orbit 3.6; orbit diameter divided by interorbital width 2.3. Measurements not included in tables 3–9 in percent of standard length: length third dorsal spine 18, eleventh 8.4, twelfth 15; length first anal spine 10, second 21, third 17; length pectoral fin 36; length pelvic fin 29; length caudal fin 33.

Coloration as in figure 8c. Spot on spinous dorsal fin between spines 7 and 9.

Comparisons. Like *Scorpaena loppei*, *S. azorica*, and *S. angolensis*, *S. annobonae* has the two pores at the symphysis of the lower jaw united. The species differs from *S. azorica* and *S. angolensis* in body shape, particularly in having a longer head and deeper body. It is possible that *S. annobonae* will normally have 10 soft dorsal rays rather than 9 as in the other three species. *Scorpaena annobonae* appears closest to *S. loppei* in spination, but differs in lacking the crest on the maxillary. Based on the presence of five branched pectoral rays at 44 mm. standard length, *S. annobonae* is a very small species probably not exceeding 100 mm. standard length.

Distribution. Known definitely only from the holotype from Annobón Island in the Gulf of Guinea in 5–26 fathoms.

Remarks. Cadenat (1945, p. 547), under the account of *S. angolensis*, listed one specimen from Principe which possibly is a specimen of the new species. He states that it has the deepest body of his specimens. There is little else in his account, however, that would suggest *S. annobonae*.

The mouth is open wide in the holotype; this affects some measurements slightly. The truncated anterior preorbital spine may not be the usual condition.

Etymology. The name is based on the type locality.

Scorpaena maderensis Valenciennes.

(A partial synonymy pertinent to the scope of the study. References without information in parentheses were not seen; some references to this species are probably based on misidentifications or mixed collections.)

Scorpaena madurensis Valenciennes, *in* Cuvier and Valenciennes, 1833, p. 463–465 (type locality Madeira). Norman, 1935b, p. 31 (synonymy; *S. rubellio* correctly included; good description from specimens of 62–140 mm. total length in British Museum). Torchio, 1962b, pp. 141–144, figs. 1–2 (two from Straits of Messina in 15 fathoms; figures good).

Sebastes maderensis, Lowe, 1840, p. 36 (mentioned). Lowe, 1843, pp. 177–182, pl. 25 (described as "new species" but with *Scorpaena madurensis* in synonymy; description; habitat; life-history notes; Madeira). Günther, 1860, p. 102 (brief description; specimens in British Museum from Madeira). Steindachner, 1867, pp. 71–73. Capello, 1867: 256 (rare; Portugal). Vinciguerra, 1883, pp. 611–612 (Madeira and Salvage Is.). Carus, 1893, p. 639. Collett, 1896, p. 15. Collett, 1897, pp. 4–5 (mostly compiled distribution). Roule, 1907, pp. vi, xvi. Jaquet, 1907, p. 2, and following (comparisons;

scales, suborbital bones, otoliths, and teeth figured; Nice). SEABRA, 1911, p. 150. CLINGNY, 1912, p. 73. FAGE, 1918, p. 102. NOBRE, 1935, pp. 98–100 (mostly compiled; *Scorpaena madurensis* Valenciennes in synonymy; synonymy; Portugal).

Scorpaena rubellio JORDAN AND GUNN, 1898, pp. 344–345 (type locality Canary Islands).

Scorpaena maderensis, CADENAT, 1945, pp. 558–561, fig. 11 (good description; specimen; from Cape Verde Islands; figure good).

NOMENCLATURAL REMARKS. Considerable confusion existed in the early literature over the use of the names "*maderensis*" and "*madurensis*." Valenciennes first described this species as *Scorpaena madurensis* (misspelling the species name). Lowe subsequently described the species as a "new species" under the name *Sebastes maderensis*, with *Scorpaena madurensis* of Valenciennes in synonymy. Most earlier authors wrongly credited the species to Lowe. Subsequently, Goode and Bean (1896) described a new species from Madeira as *Helicolenus maderensis*, which Fowler (1936, p. 917) wrongly attributed to Valenciennes under the name "*madurensis*." Since *Helicolenus maderensis* Goode and Bean is a junior synonym of *H. dactylopterus*, the use of the emended spelling for Valenciennes' "*madurensis*" (hence "*maderensis*") for the present species of the genus *Scorpaena* causes little confusion. The description by Lowe as *Sebastes maderensis* was merely a redescription as a new combination and with emended spelling.

MATERIAL EXAMINED. AZORES: USNM no. 94484 (4, about 92–100, poor condition) Terceira, collector Trelease. MADEIRA: USNM no. 94513 (1, 96) de Noronha. MEDITERRANEAN: USNM no. 196334 (6, 41–88) Beirut, Lebanon, A.U.B. Beach, H. H. Shoemaker and class, 10 October 1959, tide pool.

DESCRIPTION. Counts and measurements summarized in tables 1–10; body shape and coloration in figure 10c.

A fairly small species with no conspicuous dark spot on the spinous dorsal fin, no occipital pit, chest and pectoral-fin base scaled, slightly ctenoid scales on sides, and pores at symphysis of lower jaw separate. Dorsal fin normally with 12 spines and 9 soft rays (last double). Pectoral rays 15–16 (one with 17 on one side), rays 3 to 5 or 6 usually branched in larger specimens; no compound branching in available specimens; pectoral fin not reaching first anal spine in available material. Gill rakers including rudiments 15–18, usually 16–17; usually 5 on upper arch. Preorbital bone with two large spines over maxillary, the first pointing forward, the second to rear. Lateral surface of preorbital bone with a strongly developed ridge ending in a knob anteriorly (one specimen with ridge interrupted at middle and ending in a spine posteriorly). Suborbitals with 2 spinous points, one behind eye at end of long ridge, followed by second at end of short ridge just in front of preopercle. Upper posttemporal spine present. First preopercular spine short, second more slender than third. Cleithrum with 2 spines. Other spines as for the genus. Vertebrae 24 (six specimens). Scales on sides weakly ctenoid, vertical scale rows about 52–56; lateral-line scales

usually 25 + 2. Chest and pectoral-fin base with mostly cycloid scales, those on chest mostly embedded; most of head naked. Occipital pit absent. Two ridges on posterior part of interorbital area. Pores at symphysis of lower jaw separate and small. Skin appendages poorly developed; supraocular tentacle short, less than ½ orbit diameter; a few tentacles on lower preopercular spines, on eye, on some lateral-line scales, and on some body scales along sides, the ones on body often white in color. Orbit diameter about equal to snout, ratio snout divided by orbit 0.9–1.1; orbit into head 3.5–4.0; interorbital width into orbit diameter 2.1–2.6.

Coloration of a small specimen in figure 10c. Color variable; most conspicuous feature the small white specks in pectoral-fin axil and on body near pectoral fin. Dorsal fin blotched with brown, no dark spot. Pectoral fin with elongate dark spots, most pigment confined to rays. Pelvic fins spotted to faintly dusky. Soft dorsal fin with brown blotches or spots, more concentrated on anterior portion. Anterior part of caudal peduncle pale, followed by dark which runs on to caudal fin, this dark area usually in two large dark bars joined at center. A large, wide vertical bar across caudal fin at center formed by elongate spots on caudal rays; this vertical bar usually followed by paler spots near distal end of fin. Head and body dark with some pale areas, brown pigment more concentrated between soft dorsal fin and anal fin. Head brown, mottled with white. Anal fin with some brown pigment at base, at middle of fin, and a few brown spots near distal end of fin.

A fairly small species, probably not exceeding 150 mm. in standard length; largest available specimen 100 mm.; Norman (1935a) had specimens to 140 mm. total length.

Comparisons. *Scorpaena maderensis*, *S. canariensis*, and *S. normani* are the only species of *Scorpaena* in the eastern Atlantic which lack an occipital pit. *Scorpaena normani* has the chest and pectoral base naked, while *S. maderensis* and *S. canariensis* are the only two of the group of species of *Scorpaena* with ctenoid scales on the sides which have the chest scaled. *Scorpaena canariensis* is apparently still known only from the type; but was redescribed well by Cadenat (1945, pp. 556–558). Cadenat distinguished *S. maderensis* and *S. canariensis* on several characters, most notably the two preorbital spines in *S. canariensis* both point forward, while the posterior spine in *S. maderensis* points sharply to the rear; also, *S. maderensis* has two cleithral spines on each side while *S. canariensis* has one. Two western Atlantic species (*S. calcarata* and *S. inermis*) also lack an occipital pit, but from the shape of the interorbital bone and other features they do not seem particularly closely related to *S. canariensis* and *S. maderensis* or *S. normani*.

Distribution. *Scorpaena maderensis* is known from several localities in the Mediterranean Sea, and from the Azores, Madeira, Cape Verde Islands, and Canary Islands. It is an inshore species.

Scorpaena canariensis (Sauvage).

Sebastes (*Sebastichthys*) *canariensis* SAUVAGE, 1878, p. 117, pl. 1, figs. 1–2 (type locality Canary Islands).
Pontinus canariensis, GOODE AND BEAN, 1896, p. 255 (compiled description).
Scorpaena canariensis, CADENAT, 1945, pp. 556–558, fig. 10 (redescribed from type).

REMARKS. This species is apparently still known only from the holotype. The type was redescribed by Cadenat (1945). *Scorpaena canariensis* is distinguished from the other two eastern Atlantic species lacking an occipital pit in the key and under the account of *S. maderensis*. Counts and some measurements from Cadenat (1945) are entered in the tables.

Scorpaena mellissii Günther.

Scorpaena mellissii GÜNTHER, 1868, p. 225, pl. 19 (type locality Saint Helena). MELLISS, 1875, pp. 104–105, pl. 19, fig. 6 (Saint Helena; common name Sand or Deepwater Gurnard; not considered good as food; figure poor). CLARK, 1913, p. 53 (Saint Helena; one of 285 mm. total length).
Scorpaena laevis (not of Troschel), FOWLER, 1936, p. 927 (wrongly included *S. mellissii* in synonymy; description of *S. mellissii* from Günther).
Scorpaena mellissi, CADENAT AND MARCHAL, 1963, pp. 1288–1289 (distinguished from *S. laevis*) p. 1305 (listed).

MATERIAL EXAMINED. BMNH no. 1867.10.8.6 (1, 202, type of *S. mellissii*) Saint Helena, collected by Melliss.

DESCRIPTION (Based on the type). Counts and some measurements in tables 1–10.

A fairly large species with small cycloid scales, occipital pit present, and chest and pectoral-fin base scaled.

Dorsal fin with 12 spines and 9 soft rays. Pectoral rays 20, rays 2–12 or 13 branched; pectoral fin reaching to over anal fin. Gill rakers at least 15 on side counted, 5 on upper arch, 10 on lower arch but with an abnormal space between some rakers. Preorbital bone with 3 spines over maxillary, middle one nearer first. Suborbital ridge with 2 or 1 indistinct spinous points and many ridges (much variability expected). Upper posttemporal spine present. Other spines as for the genus. Scales small and cycloid; vertical scale rows about 68 or 70; lateral-line scales 25 + 2. Chest and pectoral-fin base scaled. Occipital pit moderate.

Günther gives the color as follows (see also his plate 19): body nearly uniformly brownish gray; head with numerous brown dots; and dorsal, caudal, and pectoral rays accomplished by series of small brown spots. (The small brown spots which occur along the sides of the rays of these fins are still visible, but the body coloration has mostly faded.)

COMPARISONS. This species appears to have no close relative in the eastern Atlantic and shows closer ties with western Atlantic species, all of which have cycloid scales and the chest and pectoral-fin base scaled. At the same time,

there is no western Atlantic species which appears particularly closely related.

Distribution. Known only from Saint Helena.

Scorpaena azorica Eschmeyer, new species.

Material examined. Holotype: USNM no. 94463 (1, 98) Terceira, Azores, collected by William Trelease, 1894.

Description. Counts and some measurements summarized in tables 1–10; body shape and coloration in figure 8a.

A species with no black spot on the spinous dorsal, occipital pit present, chest and pectoral-fin base naked, ctenoid scales on the sides, and pores at the symphysis of the lower jaw united. Dorsal fin with 12 spines and 9 soft rays (last double). Pectoral fin with 18 rays, rays 2–7 branched; compound branching of some pectoral rays; pectoral fin reaching to about over the first anal spine. Gill rakers including rudiments 15–16, all fairly short; 5 on upper arch, 8 on ceratobranchial and 2–3 on hypobranchial. Preorbital bone with 4 (5) spines over maxillary, first points forward, two smaller spines on plane with first, posterior spine larger and pointing down and slightly to rear (this spine double on right side). Suborbital ridge with 3 spines, none on preorbital, first below center of eye, second at end of ridge which passes above first spine, third between second suborbital spine and supplemental preopercular spine. Upper posttemporal spine present. Other spines as for the genus (pterotic spine and upper posttemporal spine double on right side). Interorbital ridges present, diverging anteriorly and posteriorly. Vertebrae 24. Scales on sides ctenoid, vertical scale rows about 44; lateral-line scales about 23 + 1. Chest, pectoral-fin base, and head naked. Occipital pit well developed. A single large pore at the symphysis of the lower jaw. Skin appendages poorly developed; supraocular tentacle short, less than ½ orbit diameter; no skin flaps on lower jaw. Orbit diameter about equal to snout, ratio snout divided by orbit 0.9; orbit into head 3.6; interorbital width into orbit diameter 1.9. Additional measurements (see tables 3–9) in percentage of standard length; pectoral fin 33, pelvic fin 29, both reaching to about first anal spine; third dorsal spine 17 (broken slightly at tip), eleventh 10, twelfth 14; length first anal spine 11, second 20, third 18, second and third anal spines ending at about the same point when depressed.

Coloration as in figure 8a. All fins spotted with brown; caudal fin with numerous scattered brown spots, pigment mostly confined to membranes. Some brown spots on head on lighter brown background. An indication of brown spots on sides and in pectoral axil. Pigment on body appears slightly darker between soft dorsal fin and anal fin.

Comparisons. Only one specimen in fairly soft condition is available, but the characters which distinguish the species are clear-cut. The new species falls in the group of species which have the pores at the symphysis of the lower jaw united into a single large pore. It also belongs with those having ctenoid scales

on the body, and with the chest, pectoral-fin base, and most of the head naked. Of the species, *S. loppei*, *S. annobonae*, *S. angolensis*, and *S. azorica*, which have the single pore, *S. loppei* has a unique crest on the maxillary. The other two species can be easily separated from *S. azorica* on the basis of coloration.

DISTRIBUTION. Known only from the holotype collected in the Azores.

ETYMOLOGY. The name is based on the type locality.

Scorpaena notata Rafinesque.

(A partial synonymy pertinent to the scope of the study. References without information in parentheses were not seen. Some references to this species are probably based on misidentifications or mixed collections.)

Scorpaena notata RAFINESQUE, 1810, p. 33 (type locality Sicily; poor description). FOWLER, 1936, pp. 920–922 (treated as senior synonym of *S. ustulata* Lowe). COLLINS, 1954, p. 30 (*S. ustulata* in synonymy; listed; Azores). MAURIN, 1962, p. 176, and following (collections in Mediterranean Sea). LOZANO CABO, 1963, p. 345 (listed; Spanish Sahara —Mauritania).

Scorpaena ustulata LOWE, 1840, p. 36 (type locality Madeira). GÜNTHER, 1860, pp. 110–112 (description mostly from Lowe's notes). ROCHEBRUNE, 1883, p. 63. BELLOTTI, 1888, p. 213, pl. 4a, fig. 1. BELLOTTI, 1891, p. 118. DODERLEIN, 1891, pp. 282–283 (description; synonymy; *S. notata* included in synonymy; comparisons; distribution). COLLETT, 1896, p. 10, pl. 4, fig. 15 (Strait of Pico-fayal, Azores). PELLEGRIN, 1905, p. 138 (listed). PELLEGRIN, 1906, p. 44 (Cape Blanc and Nouakchott). PIETSCHMANN, 1906, pp. 142–143 (mostly compiled). PELLEGRIN, 1907, p. 95. MURRAY AND HJORT, 1912, p. 408 (off Cape Blanco, 39–214 meters). PELLEGRIN, 1913, p. 117 (listed; Mauritania). PELLEGRIN, 1914, p. 81. ?VAILLANT *in* Roule, 1919, p. 133 (37°57′ N., 29°15′ W., in 200 meters). FOWLER, 1923, p. 34 (listed; Funchal, Madeira). CHABANAUD AND MONOD, 1926, p. 285 (Cape Blanco; compiled). SPARTA, 1941b, pp. 205–206 (description of eggs and larvae). CADENAT, 1945, pp. 545–546, fig. 5 (*S. teneriffea* in synonymy; description). ?BEN-TUVIA, 1953, p. 28 (Israel; one specimen of 88 mm.; found in 120 fathoms). COLLIGNON AND ALONCLE, 1960, p. 25 (food).

?*Scorpaena barbata* (Gronovious) GRAY, 1854, p. 116 (type in Gronovius collection, BMNH 1853.11.12.8 [Wheeler (1958, p. 237) treated this as *Scorpaena* sp., pectoral rays 17, not *S. scrofa*]).

Scorpaena teneriffea JORDAN AND GUNN, 1898, p. 345 (type locality Canary Islands).

MATERIAL EXAMINED. MEDITERRANEAN SEA: UMML no. 22840 (1, 49) Spain, near Algeciras, rocky point near S. end of Getares Beach in 0–8 feet, WAS-MED-1; UMML no. 8508 (1, 49) Spain, about ½ miles S. of Getares Beach near Algeciras, in 2–10 feet, WAS-MED-3; UMML uncataloged (1, 50) Spain, WAS-MED-11, data lost; USNM no. 48299 (1, 111), USNM no. 48305 (1, 100), USNM no. 48301 (1, 115), USNM no. 48303 (1, 110), USNM no. 48300 (2, 95–111), USNM no. 48304 (1, 83), and USNM no. 18344 (1, 62) Bay of Naples, collected by Seth E. Meek; ANSP no. 12162 (1) and USNM no. 40051 (1) Messina, Italy; ANSP no. 12167–76 (10) Mediterranean, C. L. Bonaparte no. 89, J. B. Wilson; AMNH no. 1699 (1) Max Collection; AMNH no. 1668 (2) Mediterranean. MADEIRA: ANSP no. 86850 (1, 135) Funchal market.

Description. Counts and measurements summarized in tables 1–10; body shape and coloration in figure 7a, b.

A moderate-sized species with a black spot on the spinous dorsal fin, occipital pit present, chest and pectoral-fin base naked, ctenoid scales on the sides, and pores at symphysis of lower jaw separate but close together. Dorsal fin normally with 12 spines and 9 soft rays (last split). Pectoral fin with 17–19 rays, usually 18; rays 2 to 7–8 branched in specimens over about 80 mm. in standard length; compound branching of some rays; pectoral fin reaching to about over first anal spine. Gill rakers including rudiments 15–18; 4–6, usually 5, on upper arch; 8–9 on ceratobranchial, and 2–3 on hypobranchial. Preorbital bone usually with 3 spines over maxillary (probably only 2 in very small specimens), middle one small and at base of first; posterior spine points down and slightly back. Lateral surface of preorbital bone with 1 or (usually) 2 ridges. Suborbital ridge with 3 spinous points, first below eye, second at end of ridge which runs under eye, third before supplemental preopercular spine. Upper posttemporal spine present. Preopercular spines well developed. Other spines as for the genus. Vertebrae 24 (four specimens). Scales on body ctenoid; vertical scale rows about 43–46; lateral-line scales usually 23 + 1. Chest, pectoral-fin base, and head naked. Occipital pit present. Interorbital ridges present, ending at occipital pit. Pores at symphysis of lower jaw separate but close together, about 1 pore diameter or less apart. Skin appendages moderately developed; supraocular tentacle short, less than ½ orbit diameter, and usually branched distally; small skin flaps associated with preorbital, parietal, preocular, and preopercular spines, on eye, below suborbital ridge, on snout above maxillary, and on some lateral-line scales; nasal flap large. Orbit diameter slightly larger than snout length, ratio snout divided by orbit 0.8–0.9; orbit into head 3.2–3.7; interorbital width into orbit diameter 2.0–2.8.

Coloration of preserved specimens (fig. 7a, b) brown on tan or pallid background. A large black spot at about midheight of spinous dorsal fin between about spines 6–8 to 10–11. Other fins mottled, blotched, or spotted with dark brown. Anal fin often with brown pigment more concentrated in vertical bar at about middle of fin. Sides brownish, darkest between soft dorsal fin and anal fin, followed by pale caudal peduncle. Head brownish with darker brown blotches.

A moderate-sized species, largest available specimen 135 mm. in standard length. Boutiere (1958, p. 78) had specimens to 200 mm. total length, or about 150 mm. standard length.

Comparisons. *Scorpaena notata* belongs with the group of species having the pectoral-fin base and chest naked. In most measurements and counts *S. notata* seems fairly close to the group of species having the pores at the symphysis of the lower jaw united, and in *S. notata* the pores are close together.

DISTRIBUTION. The species occurs in the Mediterranean Sea and adjacent parts of the Atlantic. It has been reported from Madeira, the Azores, and Cape Verde Islands. The southern limit of distribution appears to be about Sénégal. Boutiere (1958, pp. 57–58) reported the species as common in rocky littoral habitats off Morocco. It occurs commonly with *S. porcus*.

Scorpaena porcus Linnaeus.

(A partial synonymy pertinent to the scope of the study. References without information in parentheses were not seen. Many references to this species are probably based on misidentifications or mixed collections.)

Scorpaena porcus LINNAEUS, 1758, p. 226 (type locality Mediterranean Sea and Atlantic Ocean). RISSO, 1810, pp. 187–188 (description; [varieties may refer to *S. notata* and *S. maderensis*]). RISSO, 1826, p. 370 (compiled). CUVIER *in* Cuvier and Valenciennes, 1829, p. 330. VALENCIENNES, 1835, p. 20. VALENCIENNES, 1836, p. 462. DEKAY, 1842, p. 58 (compiled). BONAPARTE, 1846, p. 62 (listed). GÜNTHER, 1860, pp. 107–108 (synonymy; brief description; specimens in British Museum). STEINDACHNER, 1865, p. 400 (Santa Cruz and Teneriffe, Canary Islands). CAPELLO, 1867, p. 256 (compiled). STEINDACHNER, 1867, p. 676. BEAN, 1879, p. 23 (specimens from eastern Atlantic in United States National Museum). MOREAU, 1881, pp. 315–316 (description; synonymy). JORDAN AND GILBERT, 1882, p. 681 (compiled). VINCIGUERRA, 1883, p. 611 (one from Canary Islands). MEEK AND NEWLAND, 1885, pp. 394–395, 398–399 (description in key; specimens from Venice; brief synonymy). VINCIGUERRA, 1890, p. 478. DODERLEIN, 1891, pp. 279–281 (description; lengthy synonymy). VINCIGUERRA, 1893, p. 313. CARUS, 1893, p. 640. NOBRE, 1895, p. 230. PIETSCHMANN, 1906, p. 142 (brief description). SEABRA, 1911, p. 150. ROULE, 1919, p. 59 (one small specimen from the Azores in 20 meters). TUMA, 1926, pp. 484–485, 1 pl. NOBRE, 1928, p. 45. BORODIN, 1934, p. 117 (listed Mediterranean specimens). ?NORMAN, 1935a, p. 613 (specimen from off England [locality seems unlikely]). NOBRE, 1935, p. 102 (Portugal; *S. ustulata* wrongly included). FOWLER, 1936, pp. 919–920 (synonymy; description from Mediterranean specimens). FORTUNATOVA, 1940, pp. 242–247 (food and feeding). SPARTA, 1941a, pp. 109–115 (reproduction; descriptions of eggs and larvae). ANDRIASHEV, 1944a, pp. 56–60 (mode of feeding). ANDRIASHEV, 1944b, p. 323, and following (structure and function of pharyngeal apparatus). CADENAT, 1945, pp. 543–545, fig. 4 (description; *S. porcus* from New York in error). VINOGRADOV, 1948, pp. 705–707 (moulting). BEN-TUVIA, 1953, p. 28 (Israel). COLLINS, 1954, p. 30 (listed; Azores). COLLIGNON AND ALONCLE, 1960, pp. 24–25 (food). BEN-TUVIA, 1962, p. 143 (one from stomach of *Thunnus thynnus* caught off Cyprus).

?*Cottus massiliensis* FORSKAL, 1775, p. 24 (no type locality; description poor).

?*Scorpaena fasciata* COSTA, 1850, p. 3, pl. 4.

MATERIAL EXAMINED. ANSP no. 12131-62 (32 specimens) Mediterranean Sea, C. L. Bonaparte no. 88, J. B. Wilson, no other data. BLACK SEA: ANSP no. 100028 (1) Rumania, at Sulina. LEBANON: USNM no. 201147 (1, 58) Beirut, A.U.B. Beach, in tide pool, H. H. Shoemaker and class. ITALY: USNM no. 48298 (3, 39–40) Bay of Naples, Seth E. Meek; AMNH no. 1853 (2) Naples. MAJORCA: AMNH no. 9163 (1) and AMNH no. 9164 (1) Alcudia Bay, R. C. Murphy. SPAIN: USNM no. 10181 (2, about 115–139) Gibraltar, Vienna Museum; UMML no. 8509 (1, 97) near Algeciras, about ½ mile S. of Getares Beach, in 2–10 feet; UMML no. 22841 (1, 101) Santa Pola, in 2–8

feet; UMML uncataloged (3, 40–70), (1, 102), (1, 93), and (2, 41–97) all collected by Walter Starck off Spain, data lost.

Description. Counts and measurements summarized in tables 1–10; body shape and coloration in figure 9a.

A moderate-sized species with no conspicuous black spot on the spinous dorsal fin (except some juveniles), an occipital pit present, chest and pectoral-fin base naked, small emarginate scales on sides, and pores at symphysis of lower jaw tiny and separate. Dorsal fin normally with 12 spines and 9 soft rays (last double). Pectoral rays 16–18, usually 17 or 16; rays 2 to 7–10 branched in adults; compound branching of some rays in largest specimens; pectoral fin reaching to about second anal spine as maximum. Gill rakers including rudiments usually 16–18, 5–6 on upper arch, usually 8 on ceratobranchial, and 3–5 small rudiments on hypobranchial. Preorbital bone usually with 2 spinous points over maxillary forming about a right angle; posterior spine pointing down to slightly forward. Suborbital ridge with 2 or 3 spinous points; first below ridge which runs under eye, second sometimes present at end of this ridge, and third just before supplemental preopercular spine. Upper posttemporal spine present. Other spines as for the genus. Vertebrae 24 (five specimens). Scales on sides small, emarginate, with parallel sides; vertical scale rows usually about 65–70. Chest, pectoral-fin base, and head naked; usually fleshy, skin loosely clinging to body about chest and pectoral-fin base and on head. Occipital pit well developed. Interorbital ridges present, diverging at rear. Pores at symphysis of lower jaw small and separate. Skin appendages well developed; supraocular tentacle usually about equal to orbit diameter; no skin flaps on lower jaw; small dermal flaps associated with preorbital, preocular, parietal, nuchal, and preopercular spines; other tentacles at anterior nostril, below suborbital ridge, on eye, opercle flap, some body scales, and some lateral-line scales. Orbit diameter usually slightly larger than snout, ratio snout divided by orbit 0.7–1.0 (higher ratio in larger specimens); orbit into head 3.3–4.0; interorbital width into orbit diameter 1.6–2.5.

Coloration of preserved specimens as in figure 9a. Some small specimens (less than about 50 mm. standard length) with faint dark spot on spinous dorsal fin at about spines 8 or 9, absent in available larger specimens. Fins variously mottled or spotted with brown. Three usually well marked vertical bars on caudal fin, at base, middle, and distal end. Caudal peduncle pale. Pigment on body brownish with some paler areas; darkest between soft dorsal fin and anal fin. Lower sides of body and pectoral-fin axil with brown spots. Head brown, varigated and blotched with white.

A moderate-sized species, largest available specimen about 140 mm. in standard length. Boutiere (1958, p. 78) examined specimens from 80 to 130 mm. total length.

Comparisons. *Scorpaena porcus* is unique, among those species in the

eastern Atlantic with the chest and pectoral-fin base naked, in having emarginate, small scales; the others have ctenoid scales. Its affinities appear to be with the short-snouted species which have the pores at the symphysis of the lower jaw united, but the pores in *S. porcus* are well separated. The small scale size appears to be secondary. In coloration the species resembles the sympatric species *S. notata*, but larger specimens of *S. porcus* usually lack a black spot on the spinous dorsal fin and have brown spots in the pectoral-fin axil; the two species are easily distinguished by the scale size, about 65 or 70 vertical scale rows for *S. porcus* versus fewer than 50 for *S. notata*.

DISTRIBUTION. The species occurs in the Mediterranean Sea and adjacent parts of the Atlantic in shallow water. The southern limit of distribution appears to be off Sénégal. It is a littoral species common among rocks.

Genus **Scorpaenodes** Bleeker

Scorpaenodes BLEEKER, 1857, p. 371 (type-species *Scorpaena polylepis* Bleeker, by monotypy; no description). ESCHMEYER, Calif. Acad. Sci., Occ. Paper no. 76, pp. 2–4 (synonymy; description; two new species; nominal genera added to synonymy).

REMARKS. The genus *Scorpaenodes* is treated in detail in another paper (Eschmeyer, 1969). The following nominal genera are tentatively included in the synonymy of *Scorpaenodes*: *Sebastopsis* Gill, 1862; *Sebastopsis* Sauvage, 1873; *Hypomacrus* Evermann and Seale, 1907; *Sebastella* Tanaka, 1917; *Metzelaaria* Jordan, 1923; *Parascorpaenodes* Smith, 1957; and *Paronescodes* Smith, 1958.

DIAGNOSIS. Dorsal rays XIII, 8–10, usually 9; anal rays III, 4–5 usually 5; pectoral rays 15–20, some rays branched; procurrent caudal rays spinous; swim bladder present; vertebrae 24; occipital pit absent; scales on body ctenoid; head usually scaly; teeth on vomer; teeth absent on palatines; small slit present or absent behind fourth gill arch; peritoneum pale.

SPINATION. Preorbital bone with two rounded lobes over maxillary, sometimes as broad spinous points. Suborbital ridge with one row of spines and in some species one or more spines below the main spinous ridge. Supplemental preopercular spine usually present; first preopercular spine longest; second present, small in some species; third present; fourth and fifth present to virtually absent. Upper posttemporal spine absent in some species. Nasal spine absent in some species. Two ridges usually present between orbits, sometimes ending in spines (coronal spines of Smith, 1957a, but not of other authors). Tympanic (frontal) spines far to sides; also two small additional spines on frontal bones near midline sometimes present (postfrontal spines of Smith (1957) and coronal spines of Matsubara (1943)). Small spine on extrascapular bone sometimes present. A few small spinous points usually present behind orbit on fourth suborbital bone. Other spines present include the preocular, supraocular, postocular, parietal, nuchal, sphenotic (usually as group of small points), lower

posttemporal, opercular, supracleithral, and cleithral. Double spines or spurious small spinous points occasionally present.

Scorpaenodes tredecimspinosus (Metzelaar).

Scorpaena tredecimspinosa Metzelaar, 1919, p. 146, fig. 44 (type locality Aruba and Bonaire Islands, Dutch West Indies; cotype USNM no. 160660; [see lectotype designation below]).

Metzelaaria tridecimspinosa, Jordan, 1923, p. 209 (misspelled; type of new genus *Metzelaaria*). Jordan, Evermann, and Clark, 1930, p. 370 (compiled).

Scorpaenodes floridae Hildebrand *in* Longley and Hildebrand, 1940, p. 251, figure 14 (type locality south of Tortugas, Florida, in 45 fathoms; holotype USNM no. 108875, paratype USNM no. 108876). Ginsburg, 1953, pp. 41–42 (redescribed from types; thought to be synonym of *S. tredecimspinosus*). Briggs, 1958, p. 294 (compiled range).

Scorpaenodes tridecimspinosus, Ginsburg, 1953, pp. 40–41 (description based on cotype; compared with *S. caribbaeus* and *S. floridae*; misspelled).

Scorpaenodes tredecimspinosus, Böhlke and Chaplin, 1968, p. 650, illustration (description; coloration; Bahamas).

Lectotype designation. There are two species of *Scorpaenodes* in the western Atlantic, and Metzelaar (1919) apparently had both in his original description of [*Scorpaena*] *tredecimspinosus* based on four specimens. Metzelaar's description and figure fit *Scorpaenodes caribbaeus* the best; however, the cotype in the United States National Museum (USNM no. 160660), which was treated by Ginsburg (1953, pp. 40–41), represents the other species. Another nominal species, *Scorpaenodes floridae* Hildebrand (*in* Longley and Hildebrand, 1940) also represents this second species. Ginsburg (1953) suggested that *S. tredecimspinosus* and *S. floridae* were probably the same species. Designation of Metzelaar's figured specimen [= *caribbaeus*] would cause considerable confusion, since *S. tredecimspinosus* would then replace *S. caribbaeus* and also make *S. floridae* valid. Therefore, the cotype in the United States National Museum (USNM no. 160660) is designated as the lectotype of Metzelaar's *S. tredecimspinosus*. The two valid western Atlantic names are *S. caribbaeus* for the species with a high pectoral-ray count and *S. tredecimspinosus* (with *S. floridae* a synonym) for the species with the lower pectoral-ray count.

Material examined. Florida: USNM no. 108875 (1, 38, holotype of *S. floridae*) and USNM no. 108876 (1, 45, paratype of *S. floridae*) south of Tortugas in 45 fathoms; UMML no. 12346 (1, 23) 29°09′ N., 80°12′ W., in 36–40 fathoms, *Silver Bay* station 4419; UMML no. 17454 (1, 22) 24°33′–32′ N., 83°09′–15′ W., in 37 fathoms, *Gerda* station 564. The following are from Monroe County, Florida, available depths 15 to 100 feet, most from vicinity of Alligator Reef: UMML no. 3469 (1, 31), UMML no. 18942 (1, 20), UMML no. 19232 (4, 26–42), UMML no. 20091 (1, 25), UMML no. 19386 (2, 30–40), UMML no. 10861 (1, 24), UMML no. 11416 (1, 29), UMML no. 5703 (1, 31), UMML no. 22215 (1, 32), and UMML no. 4230 (1, 27). Bahamas: UMML no. 17320 (1, 31) 26°34′ N., 76°52.5′ W., in 30–32 fathoms, *Silver Bay* station

4710; UMML no. 1718 (1, 39) Andros. HONDURAS: UMML no. 12350 (1, 32) 15°56′ N., 81°12′ W., in 15 fathoms, *Oregon* station 3618. PANAMA: UMML no. 22270 (1, 28) 9°14.6′–13.5′ N., 80°21.8′–22.8′ W., in 26–27 fathoms, *Pillsbury* station 434. VENEZUELA: UMML no. 17299 (1, 36) 11°06′ N., 62°40′ W., in 30 fathoms, *Oregon* station 5033; UMML no. 17318 (1, 29) 14°02′ N., 61°00′ W., in 9–13 fathoms, *Oregon* station 5058; UMML no. 17307 (2, 21–30) and UMML no. 16299 (1, 19) 14°02.5′ N., 61°01′ W., in 13–16 fathoms, *Oregon* station 5059. DUTCH WEST INDIES: USNM no. 160660 (1, 41, lectotype of *S. tredecimspinosus*) Bonaire Island. Los ROQUES (VENEZUELA): UMML no. 15341 (2, 24–42) S. island Dos Mosquises, DdeS no. 468. DOMINICA: Several lots are present in the United States National Museum collected by Victor G. Springer during the Smithsonian Institution Dominica Survey.

DESCRIPTION. Counts and measurements summarized in tables 1–10; body shape and coloration in figure 11c.

A small species. Dorsal fin with 13 spines and 9, rarely 8, soft rays. Pectoral fin with 17 (16–18) rays; rays 2–3 to 7–8 branched in specimens over about 35 mm. standard length. Gill rakers short, 4–6 on upper arch, 7–9 on ceratobranchial, and 2–4 often indistinct rudiments on hypobranchial; total usually 17–18 (15–19). Suborbital ridge usually with 2 (1–3) spinous points, one under eye (sometimes absent) and one at end of ridge; sometimes ridge on preorbital bone ends in a spine giving a count of 3. (The lectotype of *S. tredecimspinosus* (3) and the types of *S. floridae* (1 at end) are exceptions to the usual count of 2.) No spine or spines below main ridge of spines on suborbitals. Interorbital spines and the 2 additional spines (coronal) on the frontals near the midline often absent. Other spines as for the genus. Vertebrae 24 (6 specimens). Vertical scale rows about 40–45. Orbit larger than snout, ratio snout divided by orbit 0.6–0.8 (larger specimens tend to have higher values); orbit into head 2.7–3.6 (larger specimens tend to have higher values); interorbital width into orbit diameter 1.9–3.4 (larger specimens tend to have lower values).

Coloration usually as in figure 11c, with faint dusky pigment on head and body against a pallid background. Specimens from shallower depths with more brown pigment. Pectoral, anal, caudal, and dorsal fins faintly spotted with brown or mostly clear. Black spot at end of spinous dorsal fin usually well marked. Coloration of smallest specimens about that of largest specimens.

COMPARISONS. *Scorpaenodes tredecimspinosus* differs from *S. caribbaeus* in having a lower pectoral-ray count (16–17, rarely 18 versus 18–20), in having no spines under the spinous suborbital ridge, no slit behind the fourth gill arch, usually 2 rather than 3–5 spinous points on the suborbital ridge, and in coloration. *Scorpaenodes caribbaeus* grows to a larger size and is most common in very shallow water.

DISTRIBUTION. The species is widespread in the tropical western Atlantic. Specific localities include Florida, the Bahamas, Dominica, Honduras, Panama,

Venezuela, Dutch West Indies, and Los Roques. The species usually occurs at deeper depths than *S. caribbaeus*. Depths of capture range from about 25 to 270 feet. *Scorpaenodes caribbaeus* has been taken from the shore to about 60 feet. Habitat is usually coral or rocky areas.

Scorpaenodes caribbaeus Meek and Hildebrand.

Scorpaenodes caribbaeus Meek and Hildebrand, 1928, p. 847, pl. 82 (type locality Toro Point, Panama Canal Zone). Ginsburg, 1953, pp. 38–40 (synonymy; description based on type specimens; comparisons). Robins, 1957, p. 272 (new Florida record; brief description). Cervigon, 1966, pp. 759–760, fig. 320 (description; Los Roques, Venezuela). Randall, 1968, p. 173, fig. 197 (brief description; excellent color figure). Böhlke and Chaplin, 1968, p. 651 (distinctive features; coloration; good drawing; Bahamas).

Scorpaenodes russelli Beebe and Tee-Van, 1928, p. 189, fig. (type locality Port-au-Prince Bay, Haiti). Springer and Bullis, 1956, p. 91 (Arcas Cay; listed). Mead, 1958, p. 134 (holotype from New York Zoological Society to USNM no. 170573).

Scorpaenodes triacanthus Parr, 1930, p. 115, fig. 30 (type locality Cat Island, Bahamas).

Material examined. Florida: In the UMML collection 33 lots from the vicinity of Alligator Reef, plus 8 lots from Yellow Reef (E. of Elliot Key), Ajax Reef, Long Reef, Biscayne Bay, and Lower Matecumbe Key. Depths of capture from shore to 60 feet, sizes from about 15 to 85 mm. standard length. Bahamas: In the UMML collection 11 lots from the following localities: Pigeon Cay, Bimini, Andros Island, Water Cay, Exuma Chain (Compass Cay, Oyster Cay and Cave Cay), Riding Rock Light, and Green Turtle Cay. Sizes range from about 9 to 60 mm. standard length. Depths of capture are from the shore to about 35 feet. Pectoral-ray counts for 76 additional specimens (16–78 mm.) from various localities in the Bahamas were supplied by James E. Böhlke. Haiti: UMML no. 6184 (1, 38) St. Marc Bay, 10–30 feet, CRR-Caribbean-2; UMML no. 7464 (1, 52) St. Marc Bay; USNM no. 170573 (1, 67, holotype of *S. russelli*) Port-au-Prince Bay, Haiti. Virgin Islands: UMML no. 3740 (2, 35–74), UMML no. 4277 (1, 69), UMML no. 4899 (2, 53–58), UMML no. 14964 (1), and UMML no. 8204 (1, 54) all from Saint John. Yucatan (Caribbean)-Panama: UMML no. 9713 (1, 24) Cozumel Island; UMML no. 9347 (2, 48–49) and UMML no. 9296 (3, 44–60) Banco Chinchorro; UMML no. 9405 (1, 59) and UMML no. 9461 (1, 30) Lighthouse Reef; UMML no. 9848 (2, 11–12), UMML no. 10313 (4, 50–58), UMML no. 9853 (1, 34), and UMML no. 9577 (2, 36–45) Turneffe Island; USNM no. 81619 (1, 64, holotype of *S. caribbaeus*) Toro Point, Panama Canal Zone. Dominica: Several lots are present in the United States National Museum collected by Victor G. Springer during the Smithsonian Institution Dominica Survey. Venezuela, Los Roques: UMML no. 13017 (2, 52–59) and UMML no. 22022 (1, 55) S. island of Dos Mosquises; USNM no. 179287 (6, 16–44) Los Canquises.

Description. Counts and measurements summarized in tables 1–10; body shape and coloration in figure 12a.

A colorful, moderate-sized species growing to about 85 mm. standard length. Dorsal fin with 13 spines and 9, rarely 8, soft rays. Pectoral fin usually with 19 (18–20) rays, rays 2–3 to 8–9 branched in specimens over about 45 mm. standard length. Gill rakers short, 5–8 on upper arch, 8–9 on ceratobranchial, and 0–4 often indistinct rudiments on hypobranchial; total 14–19. Suborbital ridge with 2–5, usually 4, spinous points; first on preorbital (sometimes absent), second under eye, third near posterior end, and fourth at end. A second group or row of 1 or 2 to 6 spines below main spinous ridge (fig. 2a). Spines at end of interorbital ridges and 2 close-set (coronal) spines on frontal bones near midline usually present, especially in larger specimens. Other spines as for the genus. Vertebrae 24 (4 specimens) or 23 (1). Vertical scale rows 40–45. Orbit diameter larger than snout length, ratio snout divided by orbit 0.7–0.9 (larger specimens with higher values); orbit into head 3.0–3.8 (larger specimens with higher values); interorbital width into orbit diameter 1.9–2.7 (larger specimens with lower values).

Coloration variable. Body and head variously spotted and blotched with brown (fig. 12a). Posterior portion of spinous dorsal fin with dark pigment concentrated in a poorly defined blotch. Most fins spotted with brown, pelvic fins usually slightly dusky. Pectoral fins with 1 to 3 brown bands in smaller specimens, band at base the largest; bands breaking up into spots in larger specimens. Pigment on soft dorsal fin and anal fin usually more concentrated on anterior half of fin. Caudal peduncle pale in specimens under about 30 mm. to spotted in larger specimens.

COMPARISONS. See account of *Scorpaenodes tredecimspinosus* for comparisons.

DISTRIBUTION. The species appears to be widespread in the western Atlantic in clear-water rocky or coral habitats. Specific localities include Florida, Bahamas, Haiti, Virgin Islands, Arcas Cay, Cozumel Island, islands off British Honduras, Dutch West Indies, and Los Roques. Depths of capture range from the shore to 60 feet.

Scorpaenodes africanus Pfaff.

Scorpaenodes africanus PFAFF, 1933, pp. 311–314, fig. 13 (type locality Dakar, Sénégal). NORMAN, 1935b, p. 21 (compiled). FOWLER, 1936, p. 1360 (listed). CADENAT, 1946, pp. 321–323 (description; GORÉE, Sénégal). CADENAT, 1950, p. 245 (briefly compared with *S. elongatus*; 60–90 mm.; Sénégal) p. 307 (listed).

MATERIAL EXAMINED. ANNOBÓN: UMML no. 22220 (2, 32.5–33) 1°24′ S., 5°38′ E., dredge in 5–26 fathoms, *Pillsbury* station 275 (haul 2). SÉNÉGAL: IFAN no. 50-933 (1, 50) Gorée, Delais collection, 13 September 1950; IFAN no. 50-867 (1, about 41) Delais collection, 28 August 1950; IFAN no. 58-184 (1, 50) Gorée, 13 November 1958; IFAN no. 55-4466 (1, 36) Gorée, J. Cadenat, 30 December 1955.

Description. Measurements and counts summarized in tables 1–10; body shape and coloration in figure 12b, c.

Dorsal fin with 13 spines and 9 (8 in one specimen) soft rays. Pectoral rays 17–19. Gill rakers including rudiments about 15–17, 5–6 on upper arch, 8–9 on ceratobranchial, and 2 to several poorly defined rudiments on hypobranchial. Suborbital ridge with 2 spinous points, one under the eye and one at end of ridge. No spine or spines below main ridge of spines on suborbitals. Interorbital spines and the 2 additional spines (coronal) on the frontals near the midline often absent. Supplemental preopercular spine usually present. Other spines as for the genus. Vertebrae 24 (three specimens, one with 23 also with 8 soft dorsal rays). Vertical scale rows about 45. Orbit larger than snout, ratio snout divided by orbit 0.7–0.8; orbit into head 3.0–3.5; interorbital width into orbit diameter 2.4–3.2.

Coloration of specimens from Annobón in figure 12c. Specimens from Sénégal darker brown (fig. 12b). All specimens with soft dorsal, caudal, anal, and pectoral fins spotted with brown; sometimes the pelvic fins also spotted. Smaller specimens with pigment on spinous dorsal fin concentrated as a poorly defined spot at the end of the fin.

Remarks. The specimens from Annobón Island appear to be referable to *S. africanus*, a species known from Sénégal. The two specimens from Annobón are paler in body pigmentation, but this is probably due to capture at a deeper depth. The four specimens from Sénégal and the two from Annobón agree fairly well in measurements and counts.

Comparisons. This species differs from *S. elongatus* in that it lacks the second row of spines on the suborbitals. In this character and in coloration, *S. africanus* is closely related to the western Atlantic species *S. tredecimspinosus*; the western Atlantic form averages fewer pectoral rays (17 or 16, rarely 18, versus 17–19). *Scorpaenodes africanus* differs from the Mediterranean species *S. arenai* in coloration and in having fewer spines on the suborbital ridge (2 versus 4–6).

Scorpaenodes arenai Torchio.

Scorpaenodes arenai Torchio, 1962a, pp. 112–116, fig. 1, pl. 17 (type locality Straits of Messina; good description and illustrations).

Remarks. No specimens are available for study. The description and figures as given by Torchio are good. The species is compared with *S. elongatus* and *S. africanus* under the account of *S. africanus*.

Description. (Adapted from Torchio, 1962a.) Dorsal fin with 13 spines and 9 soft rays. Pectoral rays 17–19. Lower arch with 6–8 gill rakers (possibly not including rudiments on hypobranchial). Suborbital ridge with 4–6 spinous points. No spine or spines below main ridge of spines on suborbitals. Interorbital spines and the two additional spines (coronal) on the frontals near the

midline absent(?). Supplemental preopercular spine usually present. Other spines as for the genus. Vertical scale rows about 50.

Coloration as given by Torchio shows bars on the body below the middle and end of the spinous dorsal fin, between the soft dorsal fin and anal fin, and at base of caudal fin. A dark blotch is present near the end of the spinous dorsal fin.

Scorpaenodes elongatus Cadenat.

Scorpaenodes elongatus Cadenat, 1949, pp. 665–666, fig. (type locality Sénégal). Cadenat, 1950, p. 245 (compared briefly with *Scorpaenodes africanus*; to 150 mm.; Dakar, Sénégal). Blache, 1962, p. 74 (listed; wrongly includes *Scorpaena elongata* in synonymy).

Material examined. IFAN no. 1176 (1, 87) collected at Gorée, Sénégal, 10 June 1964.

Description. (Information from Cadenat, 1949, included.) Dorsal fin with 13–14 spines and 9–10 soft rays. Pectoral rays 18–19. Five gill rakers on upper arch and 8 on lower arch. Suborbital ridge with 4 spinous points; 1 or 2 additional spines below suborbital spinous ridge. Interorbital spines present. Spines (coronal) at midline on frontals present (?) or absent. Supplemental preopercular spine present. Other spines as for the genus. Vertical scale rows about 45–50. Orbit slightly smaller than snout, ratio snout divided by orbit 0.9 (in specimen examined); orbit into head 3.7; interorbital width into orbit diameter 1.8.

Body and head with some brown pigment on a pale background. Anal fin, soft dorsal fin, caudal fin, and pectoral fins spotted with brown. No conspicuous black spot near the end of the spinous dorsal fin.

Comparisons. This species differs from the other species of *Scorpaenodes* in the eastern Atlantic in having a more elongate body. It differs from *S. africanus* in that it has the extra spines below the main row of suborbital spines. In body shape and coloration *S. elongatus* is similar to the eastern Pacific species *S. xyris*.

Distribution. The species is known only from the coast of Sénégal.

Subfamily SEBASTINAE

This subfamily has been treated by Matsubara (1943) who used osteological characters. He recognized only four genera, *Sebastes*, *Sebastiscus*, *Helicolenus*, and *Hozukius*, splitting the large genus *Sebastes* into 10 subgenera.

The most important subfamilial characters are that the second suborbital bone is more or less T-shaped, tapering posteriorly, and the suborbital sensory canal is complete, passing through the third, fourth, and fifth suborbital bones. An important event in scorpaenid evolution appears to be the attachment of the second suborbital bone to the preopercle, thus forming a strong suborbital stay, and this step occurred in the subfamily Sebastinae as presently recognized. In

the genera *Sebastes* and *Sebastiscus* the second suborbital bone does not reach the preopercle, while in *Helicolenus* and *Hozukius* the second suborbital bone attaches to the preopercle. Differences between the genera are given by Matsubara (1943, p. 175).

There is growing evidence (see Freihofer, 1963; Quast, 1965) that the mail-cheeked fishes are an artificial assemblage. I have to date only touched on osteology of scorpionfishes but have had occasion to refer to Matsubara's work frequently. Using information provided by Matsubara and other suorces, it seems likely that authors Freihofer and Quast are correct. By the time the suborbital stay is developed within the family Scorpaenidae, the fishes possessing a developed stay do not appear to be suitable ancestors for such groups as the cottids and hexigrammids. Matsubara's suggestion (1943, p. 161) that the cottids evolved from a *Setarches*-like ancestor was shown to be unlikely (Eschmeyer and Collette, 1966, p. 353). It is uncertain if other groups can be united with the scorpaenids on the basis of other characters; the suborbital stay, however, seems to have evolved more than once.

The species of the genus *Sebastes* (including *Sebastodes*) bear live young, but there is much question whether species of the genus *Helicolenus* are live-bearers (see Krefft, 1961). I have been unable to locate pre-extrusion larvae in gravid females of *H. dactylopterus* from the Atlantic. If species of the genus *Helicolenus* are oviparous, perhaps they should not be included in the same subfamily as species of *Sebastes*, as there are some morphological differences also.

Genus **Helicolenus** Goode and Bean

Helicolenus Goode and Bean, 1896, p. 248 (type species *Scorpaena dactyloptera* Delaroche, by original designation). Matsubara, 1943, pp. 258–259, 261 (osteological description based on the species occurring about Japan). Ginsburg, 1953, p. 30 (Atlantic forms).

Diagnosis. Dorsal rays usually XII, 12 (XI–XIII, 10–14); anal rays normally III, 5 (II–III, 4–6); pectoral rays 16–21; swimbladder absent, but muscle bands present; vertebrae usually 25; no occipital pit; palatine teeth present; no slit behind fourth gill arch; chest, pectoral-fin base, cheek, maxillary, and occiput scaled; peritoneum mostly black; second suborbital bone tapering posteriorly and truncated at attachment to preopercle; third through fifth suborbital bones present, housing suborbital sensory canal.

Spination. Preorbital bone with rounded lobes over maxillary. First suborbital bone without spines; second with 1 or no spines. Nasal spine present. Preocular, supraocular, and postocular spines low. Tympanic spines far to sides. Pterotic spine low, sometimes covered with scales. Parietal spine longer than nuchal spine. Coronal spine absent. Cleithral spine absent. Supplemental preopercular spine absent. Second preopercular spine longest, first about equal to third, fourth and fifth moderate. Other spines present include the sphenotic, upper and lower posttemporal, and supracleithral.

SPECIES. The species of the genus *Helicolenus* are poorly understood and several species have been erroneously referred to it. Some differences mentioned in the literature for the different species have resulted from varied methods of counting and measuring, particularly counts of gill rakers and scales, and from changes in proportional measurements with growth.

Two species are recognized in the Atlantic Ocean: *Helicolenus dactylopterus* and *H. tristanensis*, the latter confined to Tristan da Cunha. *Helicolenus dactylopterus* includes two subspecies. Another species occurring about Japan (*H. hilgendorfi*) is doubtfully distinct from *H. dactylopterus* and has been synonymized with it by some authors. *Helicolenus dactylopterus* rounds the tip of South Africa, but no specimens are known from the northern Indian Ocean. A fourth species occurs at New Zealand and Australia (*H. papillosus*, with *H. percoides* and *H. maccullochi* apparent synonyms). A fifth species, *H. lengerichi*, occurs in the eastern Pacific off Peru and Chile. The species described from Hawaii in this genus (*Helicolenus rufescens* Gilbert, 1905; holotype USNM no. 51628, examined) is not a species of *Helicolenus* but belongs rather to the subfamily Scorpaeninae. *Helicolenus microphthalmus* Norman, 1935, described from two specimens supposedly from the Yorkshire coast of England, was placed in the synonymy of the Oriental species *Sebastiscus marmoratus* by Wheeler and Eschmeyer (1968). The locality data for the specimens used by Norman are suspect.

ATLANTIC SPECIES. Of the two species of *Helicolenus* occurring in the Atlantic, one is confined to Tristan da Cunha (*H. tristanensis*) and the other (*H. dactylopterus*), is widespread. The population of *H. dactylopterus* occurring off Uruguay and Argentina stands apart from the other populations in some measurements and appears more isolated in distribution; this population is treated as the subspecies *H. dactylopterus lahillei*. The subspecies *H. d. dactylopterus* is recognized as composed of 4 populations: (1) Northeastern Atlantic and Mediterranean, (2) Gulf of Guinea, (3) South Africa, and (4) northwestern Atlantic from Venezuela to Nova Scotia. The three populations in the eastern Atlantic show gradients in several characters, the population in the Gulf of Guinea being intermediate between specimens from the northeastern Atlantic and from South Africa; presumably the characters will show a smooth gradient when material is available from intermediate localities. A more comprehensive study is needed, however.

Helicolenus dactylopterus (Delaroche).

A partial synonymy pertinent to the scope of the study. References without information in parentheses were not seen. Entries are listed separately for the four populations of the subspecies "*dactylopterus*" and for the subspecies "*lahillei*."

Helicolenus dactylopterus dactylopterus.

Population 1. Northeastern Atlantic and Mediterranean

?*Scorpaena malabarica* Schneider *in* Bloch and Schneider, 1801, p. 194.

Scorpaena dactyloptera Delaroche, 1809, p. 337, pl. 22, fig. 9 (type locality Barcelona). Risso, 1810, pp. 186–187 (description; Nice). Risso, 1826, p. 369 (compiled). Günther, 1889a, p. 417 (new to British fauna; several specimens from 250 fathoms). Günther, 1889b, p. 6 (larvae taken by *Challenger* off the Cape Verde Islands). Smitt, 1892, p. 154, fig. 43 (description; synonymy; good figure). Sim, 1893b, pp. 204–206 (correction of misidentification (Sim, 1893a) as *Sebastes norvigicus*). Nelson and Clarke, 1893, p. 81 (one from North Sea; compared with *Sebastes viviparus*). Clarke, 1893, pp. 94–101, pl. 2 (description; distribution; synonymy; one specimen from North Sea). Howse, 1894, p. 174 (one specimen from off Norway). Holt and Calderwood, 1895, p. 409, pl. 52, fig. 1. Holt and Byrne, 1908, pp. 9–20, pl. I (good description; color in life; numerous specimens from Ireland; summary of distribution). Nybelin, 1948, p. 85 (one specimen of 90 mm. from 35°34′ N., 6°32′ W., in 409 meters; counts). Went, 1953, p. 107 (one specimen from Dingle Bay, Ireland, in 50 fathoms; rare within 100 fathoms).

Sebastes imperialis Cuvier *in* Cuvier and Valenciennes, 1829, p. 167. Lowe, 1843, p. 177, pl. 24 (description; Madeira). Bonaparte, 1846, p. 62 (listed; "*Sciaena*" *malabarica* Schneider questionably in synonymy; *Scorpaena dactyloptera* in synonymy). Capello, 1867, p. 255 (*Sebastes dactylopterus* in synonymy; Portugal). Capello, 1881, p. 11. Osorio, 1895, p. 260 (listed; Mattosinhes, Portugal).

Sebastes kuhlii (not of Bowdich), Valenciennes, 1835, pl. 2, fig. 1.

Sebastes dactylopterus, Günther, 1860, p. 99 (brief description; specimens in British Museum). Moreau, 1881, pp. 317–321, fig. 117 (description; synonymy; Mediterranean specimens). Vaillant, 1888, pp. 368–370 (description; otoliths; specimens from Gulf of Gascogne, coast of Spain, Morocco, Canary Islands, Soudan, Cape Verde, and Azores). Carus, 1893, p. 638. Nobre, 1895, p. 230. Collett, 1896, p. 12. Vieira, 1898, p. 32. Roule, 1907, p. xv. Jaquet, 1907, p. 1, and following, figs. (comparisons; scales; otoliths; teeth). Koeford, 1927, p. 130 (10 specimens; *Michael Sars* station 21, 35°31′ N., 6°35′ W., in 535 meters). Nobre, 1935, pp. 95–96 (synonymy; description; Portugal; not fig. 40).

Sebastes norvigicus (not of Ascanius), Sim, 1893a, p. 47 (misidentified).

Helicolenus dactylopterus, Goode and Bean, 1896, pp. 249–250 (description; compared with *H. maderensis*). Vaillant, *in* Roule, 1919, p. 132 (*Princesse-Alice* stations 866 and 899). Norman, 1935a, p. 612 (mostly compiled; one specimen from 5 fathoms [depth probably wrong]). Norman, 1935b, pp. 24–25 (synonymy; description). Fowler, 1936, pp. 916–917, fig. 386 (synonymy; description from Mediterranean specimens). Collins, 1954, p. 30 (compiled). Andriyashev, 1954, pp. 339–340, figs. 191–193 (brief synonymy; description; comparisons with *Sebastes*). Ben-Tuvia, 1962, p. 143 (11 specimens from off Cyprus; dorsal and anal ray counts). Maurin, 1962, p. 172, and following (collections in Mediterranean Sea and adjacent Atlantic; depth distribution). Lozano Cabo, 1963, pp. 335, 345 (listed; Spanish Sahara-Mauritania).

Sebastes dactyloptera, Jaquet, 1906, pp. 1–6, pl. 1 (abnormal anal fin in three specimens).

Helicolenus maderensis Goode and Bean, 1896, pp. 250–252 (in part; Madeira only; type restricted by Ginsburg, 1953, p. 35, to western Atlantic). Fowler, 1936, pp. 917–918 (confused with *Scorpaena maderensis*; description from Goode and Bean, 1896).

Scorpaena (*Helicolenus*) *dactylopterus*, Fage, 1918, p. 102.

Helicolenus dactylopterus dactylopterus, Ginsburg, 1953, p. 32 (description; specimens from

Norway, Azores, Bay of Naples, and Genoa; comparisons with specimens from NW. and SW. Atlantic).

Population 2. Gulf of Guinea

Helicolenus dactylopterus, Poll, 1959, pp. 173–175, fig. 63 (description; good figure; West Africa, 1 from 7°16′ S., 4 from 10°45′ S., and 1 from between 0° and 17° S.). Blache, 1962, p. 74 (listed).

Population 3. South Africa

Sebastes maculatus Cuvier *in* Cuvier and Valenciennes, 1829, p. 343 (type locality South Africa). Günther, 1860, p. 101 (compiled). Gilchrist, 1902, p. 119 (compiled).

Sebastichthys maculatus, Sauvage, 1891, p. 290 (description; Madagascar).

Helicolenus maculatus, Barnard, 1927, pp. 907–908 (brief description; False Bay, Agulhas Bank to Natal, in 50–300 fathoms). Fowler, 1934, p. 482 (description; one specimen of 218 mm. from Natal). Davies, 1949, pp. 26–29 (South Africa; 50–300 fathoms; abundant about 200 fathoms; food; spawn probably in November). Smith, 1949 (also later editions), p. 369, pl. 83, no. 1034 (brief description; from Walfish Bay to Natal, in 30–300 fathoms). Smith, 1957b, pp. 86–87, pl. 6, fig. 2 (description; *H. lahillei* [wrongly thought by Smith to be from Angola] doubtfully distinct).

Helicolenus dactylopterus, Sanchez, 1966, p. 153, illustration (compiled; Angola).

Population 4. Atlantic coast of the United States, Gulf of Mexico and the Caribbean Sea

Scorpaena dactyloptera, Jordan and Gilbert, 1882, p. 679 (specimens from off Chesapeake Bay). Garman, 1896, p. 79 (off Sand Key Light in 105 fathoms).

Sebastoplus dactylopterus, Goode and Bean, 1883, p. 214 (one specimen from *Blake* station 311, 39°59.5′ N., 70°12′ W., in 143 fathoms).

Helicolenus maderensis Goode and Bean, 1896, pp. 250–252, pl. 68, fig. 244 (in part; western Atlantic specimens only [restricted by Ginsburg 1953, p. 35, lectotype from *Fish Hawk* station 897, 37°25′ N., 74°18′ W., in 158 fathoms, USNM no. 26627]). Evermann and Kendall, 1900, p. 88 (compiled Florida record). Bigelow and Walsh, 1925, p. 313, fig. 148 (compiled). Norman, 1935b, p. 25 (off Long Island, New York). Longley and Hildebrand, 1941, p. 165 (brief description; color; Tortugas, Florida, in 100–300 fathoms).

Helicolenus dactylopterus, Evermann and Kendall, 1900, p. 88 (compiled Florida record). Bigelow and Schroeder, 1953, pp. 437–438, fig. 224 (compared with *Sebastes marinus*; color; area about Gulf of Maine in 68–240 fathoms). Springer and Bullis, 1956, p. 90 (Gulf of Mexico collections by the vessel *Oregon*). Musick, 1966, p. 877 (distribution in Gulf of Maine; one from 32 fathoms).

Helicolenus thelmae Fowler, 1937a, p. 300, fig. 5 (type locality near Gulf Stream off Cape May, New Jersey).

Helicolenus dactylopterus maderensis, Ginsburg, 1953, p. 33–35 (compared with other subspecies; specimens from Massachusetts to Gulf of Mexico).

Helicolenus dactylopterus thelmae, Briggs, 1958, p. 294 (compiled range).

Helicolenus dactylopterus lahillei.

Helicolenus dactylopterus, Lahille, 1913, pp. 5–7, pl. 2 (description; Province of Buenos Aires, in 250 meters). Fowler, 1917, p. 5 (name only; Argentina). Devincenzi, 1924, pp. 249–250 (synonymy; Uruguay).

Helicolenus lahillei Norman, 1937, p. 124, fig. 68 (type locality coasts of Uruguay and northern Argentina). De Buen, 1950, p. 120 (compiled).

Helicolenus uruguayensis Fowler, 1943, pp. 326–329, figs. 18–19 (type locality off Uruguay; holotype ANSP no. 70325; paratypes (2) ANSP nos. 70326–7). De Buen, 1961, p. 120 (three specimens; 60 miles ESE. of Lobos Island in 67 meters).

Helicolenus dactylopterus lahillei, Ginsburg, 1953, p. 36 (good description; compared with specimens from northeastern and northwestern Atlantic).

Material examined.

Helicolenus dactylopterus dactylopterus. Population 1. Northeastern Atlantic and Mediterranean Sea: IIP uncataloged (2, 122–128) Mauritania, collected by F. Cervigon; USNM no. 188491 (4, 182–250) Azores, San Miguel, collected by Bruce B. Collette; ANSP no. 12208-11 (3, 63–192, soft condition) Mediterranean, through J. B. Wilson. Population 2. Gulf of Guinea: UMML no. 21771 (4, 51–83) 4°56′ N., 5°01′ W., in 180–270 fathoms, *Pillsbury* station 51; UMML no. 15615 (23, 43–98) 4°38′ N., 9°20′ W., in 170–200 fathoms, *Pillsbury* station 73. The following are from *Geronimo* Cruise 2: USNM uncataloged (2, 34–92) 3°02′ S., 9°21′ E., in 300 meters, station 220; USNM uncataloged (1, 180) and TABL uncataloged (1, 42) 1°26.4′ S., 8°24′ E., in 400 meters, station 199. TABL uncataloged (2, 185–195) 1°57′ S., 8°47′ E., in 400 meters, station 205. TABL uncataloged (1, 30) and (4, 65–82) 2°31′ S., 8°51′ E., in 300 meters, station 213. Population 3. South Africa: USNM uncataloged (1, 163) 25°32′ S., 33°24′ E., in 450–455 meters, *Anton Bruun* Cruise 8, station 396b; ANSP no. 55316 (1, 164) Natal, Durban, collector W. H. Bell-Marley. Population 4. Atlantic coast of the United States, Gulf of Mexico and the Caribbean Sea: Florida Straits. The following specimens are from the Straits of Florida between 79°59′ W. to 83°37′ W. and 24°21′ N. to 25°41′ N.; depths of capture are from 200–300 fathoms; all are in the UMML collection: no. 20799 (2, 125–134) *Gerda* station 766; no. 12385 (1, 136) *Gerda* station 66; no. 13730 (2, 128–153) *Oregon* station 4373; no. 16192 (2, 128–159) *Oregon* station 4340; no. 16202 (5, 104–151) *Oregon* station 4339; no. 16219 (18, 88–185) *Oregon* station 4341; no. 13973 (27, 60–124) *Oregon* station 4353; no. 16190 (5) *Oregon* station 4523. Northern Gulf of Mexico: UMML no. 16168 (2, 101–158) 29°12′ N., 86°42′ W., in 225 fathoms, *Oregon* station 4073. Venezuela: UMML no. 14015 (2, 84–88) 11°46′ N., 69°17′ W., in 240 fathoms, *Oregon* station 4425; UMML no. 14019 (1, 89) 10°55′ N., 67°01′ W., in 230 fathoms, *Oregon* station 4456; UMML no. 16208 (1, 210) 11°26′ N., 68°25′ W., in 280 fathoms, *Oregon* station 4432; UMML no. 13507 (1, 212) 11°46′ N., 69°15′ W., in 240 fathoms, *Oregon* station 4417; UMML no. 14269 (1, 322) 11°49′ N., 69°24′ W., in 300 fathoms, *Oregon* station 4412. Additional specimens are present in the UMML fish collection.

Helicolenus dactylopterus lahillei. ANSP no. 70325 (1, 226) and nos. 70326–7 (2, 178–179) holotype and two paratypes of *H. uruguayensis*, Uruguay, L. P.

Barattini, 1935; USNM no. 86697 (1, 164) and no. 86698 (1, 170) Uruguay, Pesca de Albuda, H. M. Smith.

DESCRIPTION. (See also the generic Diagnosis and Spination.) Measurements and counts summarized in tables 11–15; coloration in figure 13a, b.

Dorsal fin normally with 12 spines (11–13) and 12 or 11 (14–10) soft rays (last double). Anal fin normally with 3 spines and 5 soft rays (last double). Pectoral rays most frequently 19 (16–21). Gill rakers well developed, 7–9 on upper arch, 16–21 on lower arch, varying with geographic area (table 12). Spination as for the genus. Presence or absence of a spine on the suborbitals variable, possibly showing some variation with geography. Vertebrae usually 25. Scales ctenoid; vertical scale rows about 55–80, varying with geography. Chest, cheek, and maxillary usually scaled; snout and ventral part of head usually naked; no tentacles on head or body. Buccal cavity and peritoneum black, usually fades to brown in preservative. Symphyseal knob on lower jaw poorly developed. Some measurements, especially those showing differences between the different populations, are given in the tables.

Coloration variable. Smaller specimens (fig. 13b) with black pigment near end of spinous dorsal fin. Pigment on body in bands in smaller specimens. Preserved larger specimens with bands or diffuse dusky markings (fig. 13a). In life specimens have bands of red along the sides, these frequently retained as brown pigment in preservative; bands located as follows: below anterior dorsal spines, below middle dorsal spines, below posterior dorsal spines (about spines 9–11), and two below the soft dorsal fin joining at about the lateral line, plus one at the base of the caudal fin.

POPULATION DIFFERENCES. Counts of fin rays (table 11) do not appear to vary significantly; there is some indication that the pectoral-ray counts are higher in the Gulf of Guinea among specimens from the eastern Atlantic. The southern specimens in the northwestern Atlantic average slightly higher than specimens from more northern areas as shown by comparing my counts for pectoral rays (mostly specimens from Tortugas and Venezuela) with those of Ginsburg (mostly specimens from the northern Gulf of Mexico and the Atlantic coast of the United States).

Counts of gill rakers (table 12) vary geographically, with an increase in number of gill rakers in the eastern Atlantic from lowest counts in the northeastern Atlantic to highest counts for specimens from South Africa. The specimens in the northeastern Atlantic have about the same gill-raker count as those from the northwestern Atlantic.

Some measurements vary with geography. Specimens from the southwestern Atlantic (*H. d. lahillei*) clearly average a smaller head (table 13), smaller orbit (table 14), wider interorbital space (table 15) and shorter jaw (table 15). Evaluation of smaller variations in counts and measurements within and between

the populations of *H. d. dactylopterus* awaits a more thorough treatment using more specimens and analysis by size groups.

The vertical scale rows are somewhat difficult to count and frequently some scales are missing, but the scale size does vary geographically. The scales are smallest in specimens of *H. d. lahillei*, the vertical scale rows usually numbering in the low to middle seventies. Scale rows usually number in the middle sixties in specimens from the northwestern Atlantic, and in the upper sixties in the northeastern Atlantic and Gulf of Guinea. My specimens from South Africa lack some scales but have about 55–60 vertical scale rows, the range given by Smith (1957, p. 86).

The presence or absence of a spine on the suborbitals needs further study. Ginsburg (1953, p. 35) used the usual absence of a spine on the suborbital in eastern Atlantic specimens as the chief differentiating character between the eastern and northwestern Atlantic populations, and he felt the differences to be of subspecific magnitude. Only one specimen of the 7 he examined from the northeastern Atlantic had a spine (one side) on the suborbital, the other 6 having none. In my 9 specimens from this area, 2 had a spine of lump on both sides, 6 had a spine on 1 side and 2 lacked spines on both sides. I got roughly the same ratio for 5 specimens from off the east coast of the United States; 1 had both spines, 1 had none, and 3 lacked spines. The absence of a spine or presence on only one side appears to be more frequent in larger specimens. Counts for specimens from the Florida Straits (those less than 125 mm. standard length in parentheses) are 46 (18) with both spines, 3 (6) with 1, and 1 (0) with none. In specimens from the Gulf of Guinea (mostly under 125 mm.) 29 had spines on both sides, 8 on one side, and 1 with none. Both specimens examined from off South Africa lack spines, and Smith (1957b, p. 87) says the suborbital spine is usually absent.

Distribution and ecology. The subspecies *H. d. lahillei* is restricted to the coasts of Argentina and Uruguay. The subspecies *H. d. dactylopterus* is found from Venezuela north to Nova Scotia and in the eastern Atlantic from Norway south to the southern tip of South Africa.

The usual depth range inhabited by the species is from about 100 to 300 fathoms. Shallowest captures appear in higher latitudes; Musick (1966, p. 877) reports one from 32 fathoms in the Gulf of Maine, Went (1953, p. 107) lists one from 50 fathoms off Ireland and states that the species is rare within 100 fathoms; Smith (1949) gives the depth range as 30 to 300 fathoms off South Africa. Specimens examined from Florida and Venezuela were all from about 200–300 fathoms; Longley and Hildebrand (1941, p. 165) list the range as 100–300 fathoms off Tortugas, Florida.

The species is a general predator which feeds on both pelagic and benthic organisms. Davies (1949, pp. 26–29) reported that, in South African waters,

Myctophum humbolti and other pelagic organisms formed a part of the diet, but benthic fishes and crustaceans composed most of the diet.

Helicolenus tristanensis Sivertsen.

Helicolenus tristanensis SIVERTSEN, 1946, pp. 17–19, fig. 12, pl. 1, fig. 1, and pl. 6, figs. 3–4 (type locality Tristan da Cunha, in 40–50 meters).

DESCRIPTION. (No specimens are available for study, but the description and photographs as given by Sivertsen are good. The description below is taken from Sivertsen.)

Dorsal fin with 12 spines and 12–14 soft rays (possibly 11–13 soft rays if the last double element is counted as 1). Anal fin with 3 spines and 5 soft rays (last double). Pectoral fin with 18–19 rays, first 1 or 2 simple, next 8–9 branched, lower 8–9 simple with distal half of rays free; middle rays slightly prolonged. Gill rakers on lower arch 19–20. The spination appears to agree well with that described for the genus; no spine is shown on the suborbitals. Scales ctenoid; vertical scale rows about 70–80; tubed lateral-line scales 28–30. Chest, cheeks, and maxillary scaled. Buccal cavity and peritoneum black. Body with numerous small dark brown spots, somewhat confluent on the back and more widely spaced on sides, with belly pale. Dorsal fin, especially lower half, with numerous irregularly-spaced small brown spots. Some red in life. Sivertsen gives the following measurements (p. 17), "Depth 3⅛–3⅜, length of head 2½–2⅗ in length of body. Eye 3⅕–3⅗ in length of head. Snout ¾, interorbital width about ½ diameter of eye."

COMPARISONS. *Helicolenus tristanensis* is closest to *H. dactylopterus lahillei* from Uruguay and Argentina in some measurements, particularly in having a relatively small orbit, wide interorbital in relation to the orbit, and small orbit in relation to the snout length. Also, these two species agree in having small scales on the body, smaller than specimens of *H. dactylopterus* from other areas of the Atlantic. Sivertsen (p. 17) shows the middle pectoral rays elongate; this occurs in specimens of *H. dactylopterus*, but not to the extent shown by specimens of *H. tristanensis*. *Helicolenus tristanensis* differs most notably in coloration; the intense spotting of *H. tristanensis* is lacking in *H. dactylopterus*. In coloration *H. tristanensis* is closest to *H. papillosus*, a species occurring at Australia and New Zealand.

DISTRIBUTION. The species is known only from Tristan da Cunha, apparently only from the original description based on three specimens caught at a depth of 40–50 meters.

Genus **Sebastes** Cuvier

Only the single species occurring in the South Atlantic is treated in detail. Three North Atlantic species are now usually recognized, *S. marinus*, *S. viviparus* and *S. mentilla*. A recent comprehensive treatment of the North Atlantic species

(Templeman, 1959) serves as a guide to the literature and provides information to distinguish the species. Matsubara (1943, p. 179) gives a detailed description for the genus based on osteological characters.

Sebastes capensis (Gmelin).

Perca dorso monopterygio Gronovius, 1763, pp. 88, 293.
Scorpaena capensis Gmelin, 1788, pp. 1219–1220 (original description from Gronovius).
Scorpaena africana Lacépède, 1802, p. 266 (new name; *S. capensis* in synonymy).
Sebastes capensis, Cuvier *in* Cuvier and Valenciennes, 1829, p. 341. Quoy and Gaimard, 1834, pp. 690–691, pl. 11, fig. 3 (Cape of Good Hope). Smith, 1849, pl. 22, fig. 1, plus 2 pp. (figure adequate; description with some errors, for example anal soft rays 5; fig. 2 and description of *S. maculatus* also this species). Günther, 1860, pp. 96–97 (synonymy; specimens in British Museum). Gilchrist, 1902, p. 119 (compiled).
Sebastes maculatus (not of Cuvier), Smith, 1849, pl. 22, fig. 2, plus 2 pp. (figure of *S. capensis*; description probably of specimen of different size than in fig. 1 of *S. capensis*).
Perca afra Gronovius *in* Gray, 1854, p. 113.
Sebastodes capensis, Jordan and Evermann, 1898, p. 1833 (synonymy; description from Günther; state probably differs from *Sebastodes oculatus* from Chile).
Sebastichthys capensis, ?Sauvage, 1891, pp. 289–290 (Madagascar). Norman, 1935b, p. 57 (Tristan da Cunha; one of 340 mm. by hand-line in 40 meters; no description; also obtained at Gough Island by vessels *Scotia* and *Quest*). Sivertsen, 1946, pp. 19–21, figs. 13–14 (Tristan da Cunha; good description from specimens of 170–370 mm. total length; one larva questionably included). Davies, 1949, p. 26 (shallow water on west coast of South Africa in 12–150 fathoms; common name Jacoperver). Smith, 1949 (also later editions), p. 372, pl. 85 (brief description; 20–150 fathoms; from Cape to Saldanha Bay; taken on lines, also along shore in rocky areas in False Bay; color plate). Wheeler, 1958, pp. 238–239, pl. 32 (holotype of *S. capensis* a dried skin from the Gronovius Collection; description; plate good; wrongly states 12 dorsal spines).

Nomenclatural remarks. Wheeler (1958) was able to locate the holotype of *Scorpaena capensis* in the Gronovius Collection housed in the British Museum; this specimen formed the basis of the description by Gronovius (1763), Gmelin (1788), and Gronovius *in* Gray (1854).

The species *Sebastes oculatus* (Cuvier, 1833) which occurs from the coast of Chile to the Falkland Islands is doubtfully distinct from *S. capensis* (see Distribution and Remarks).

Material examined. BMNH no. 1935.5.2.176 (1, 280) Tristan da Cunha, *Discovery* station 4, hand-line in 40 meters.

Description. (Based on one specimen and information given by Sivertsen, 1946, pp. 19–21.) Body shape and coloration in figure 13c.

Dorsal fin with 13 spines and 13–14 soft rays (last double). Anal fin with 3 spines and 6 soft rays (last double). Pectoral rays 18–19, lower 9–10 simple. Gill rakers including rudiments 9 + 19–20; longest rakers near angle, about ½ length of gill filaments and ¼–⅓ orbit diameter. Vertebrae 26. Preorbital bone with rounded lobes over maxillary. No spines on suborbital bones. Spines absent include the coronal, nuchal, pterotic, and sphenotic. Nasal spines well

developed. Preocular and postocular spines present; supraocular spine present on left and absent on right in specimen examined. Tympanic spines low. Parietal spines long. Upper posttemporal spine well developed; lower posttemporal spine small. Upper 3 preopercular spines elongate, fourth blunt, fifth very blunt. Supracleithral spine broad. Cleithrum rounded, without sharp spine. Opercular spines well developed. Knob present at symphysis of lower jaw. Ridges between orbits low, concave between. Scales ctenoid, vertical scale rows about 75, difficult to count because of numerous smaller accessory scales; lateral line with 36–43 tubed scales. Branchiostegal membranes and upper and lower jaws naked. Interorbital area and isthmus scaled.

Measurements in percent standard length for the specimen examined are as follows (upper jaw will not close completely): Head 43; depth 36; orbit 10; snout 11; interorbital width 5.5; jaw 21; predorsal 38; first anal spine 7; second anal spine 14; third anal spine 12; dorsal spines short, longest dorsal spine (fourth) 10, twelfth 6, thirteenth 8; pelvic fin 21, falling just short of vent; pectoral fin long, 28, extending past vent; caudal fin truncate, least length 17; orbit into snout 1.1; interorbital width into orbit diameter 1.8; orbit into head 4.3. Useful measurements given by Sivertsen are as follows: Head 2.4–2.6 in length of body; eye 3.5 (smaller specimens) to 4.9 (larger specimens) in length of head; snout 1.2 (smaller specimens) to 0.9 (larger specimens) in eye diameter; interorbital width 0.5–0.75 of eye diameter.

Other characters which are useful in distinguishing *S. capensis* from other species in this subfamily (see Phillips, 1957; and Matsubara, 1943) are as follows. Anus situated well in advance of anal-fin origin. End of maxillary extends almost to below rear of orbit. Terminal profile of anal fin with an anterior slant. Lower jaw extends slightly beyond upper jaw with mouth closed. The base of the cranium (parasphenoid) relatively flat (in the sense of Matsubara, 1943). Second suborbital bone long, tapering to a point, and almost reaching the preopercle.

The coloration is described by Smith (1849), J. L. B. Smith (1949), and by Barnard (1927). Barnard says the color is red, shading to orange below; several silvery-white or pinkish irregular spots on the sides above the lateral line; fins red; membrane of spinous dorsal fin mottled with brown; iris golden. The coloration of the preserved specimen (fig. 13c) agrees with that described by Norman (1937, pp. 122–123) for a specimen of *S. oculatus* from Chile, with an indication of pale areas on the sides located in the same areas as shown schematically by Norman (1937, fig. 67). This also agrees with the pale areas shown by Smith (1849, fig. 1) and J. L. B. Smith (1949, pl. 85) for specimens of *S. capensis* from South Africa. The upper part of the back is dark between the pale areas.

Distribution and remarks. The present species may be shown to occur from Chile, south through the Straits of Magellan, and east to the Falkland

Islands, Tristan da Cunha, and the southwestern tip of South Africa. Steindachner (1881) first suggested that *S. oculatus* from Chile was a synonym of *S. capensis*. Norman (1937, pp. 122–123) compared specimens of both species and found only a slight difference in the length of the dorsal spines; a difference which may be related to size of specimens. Some additional species described from the Pacific coast of South America are also doubtfully distinct from *S. oculatus*; for example, Norman (1937, p. 122) suggested that *S. chilensis* Steindachner was doubtfully distinct from *S. oculatus*, and that *S. darwini* Cramer was closely related, but he had no specimens of *S. darwini*. De Buen (1960) included *S. jenynsi* Abbott in synonymy of *S. oculatus*. Additional study is needed.

Subfamily SETARCHINAE

(See Eschmeyer and Collette, 1966, for a detailed treatment.)

Diagnosis. Lateral line a continuous trough covered by thin membranous scales; scales small and cycloid; cranium thin and cavernous, bones weakly ossified; second suborbital bone uniformly broad or gradually becoming wider posteriorly, never T-shaped, and without spines in adults; third and fourth suborbital bones absent; no fleshy appendages on head or body; vertebrae 24.

Remarks. The subfamily Setarchinae has been treated on a world-wide basis by Eschmeyer and Collette (1966). This small subfamily contains three genera and four species; two of the genera, *Ectreposebastes* and *Setarches*, are each represented by a species which occurs on both sides of the Atlantic.

Genus **Setarches** Johnson

Setarches Johnson, 1862, p. 177 (type species *Setarches güntheri*, by monotypy). Eschmeyer and Collette, 1966, pp. 355–356 (redefined genus; included *Bathysebastes*, *Lythrichthys*, and *Scorpaenella* in synonymy; two species recognized: *Setarches longimanus* from the Indo-Pacific and *S. guentheri* from the western Pacific, Indian, and Atlantic Oceans).

Diagnosis. Dorsal rays normally XII, 9–10; anal rays III, 5 (juveniles with 2 spines); pectoral rays 20–25; alimentary canal black; swimbladder present.

Setarches guentheri Johnson.

(See Eschmeyer and Collette, 1966, pp. 357–365, for a detailed treatment.)

Setarches guentheri Johnson, 1862, pp. 177–179 (type locality Madeira).

Additional references.

Setarches parmatus, Evermann and Kendall, 1900, p. 88 (compiled Florida records). Longley and Hildebrand, 1941, pp. 166–167 (brief description; Tortugas, Florida). Briggs, 1958, p. 294 (compiled Florida records). Bullis and Thompson, 1965, p. 54 (collections by U. S. Fish and Wildlife Service exploratory fishing vessels). Moe, and others, 1966, p. 81 (specimens in Florida Board of Conservation collection).

Setarches guentheri, Lozano y Rey, 1943 [Not seen.]. Blache, 1962, p. 74 (compiled).

Setarches remiger, Fowler, 1949, p. 107 (listed).

Setarches güntheri, Lozano Cabo, 1963, p. 345 (listed; Spanish Sahara-Mauritania).

CORRECTION OF EARLIER MISTAKE. Eschmeyer and Collette (1966, p. 360, table 2) wrongly give the anal soft rays as 4 (four specimens), 5 (154) and 6 (95); the number of specimens with 6 soft rays should have been 1 rather than 95.

DISTINGUISHING FEATURES. The two Atlantic species of the subfamily are easily separated from species of other subfamilies by the characteristic trough-like lateral line and the reduced ossification. *Setarches guentheri* differs from *Ectreposebastes imus* in having 20–25 pectoral rays, rather than 20 or fewer, having the orbit diameter about equal to the interorbital width, rather than about twice the interorbital, and in having normally 5 rather than 6 soft rays in the anal fin.

DISTRIBUTION. The species was treated by Eschmeyer and Collette (1966) as occurring from Hawaii west to the western Atlantic, with some geographic variation in counts and measurements. In the western Atlantic the species is widely distributed from 39°57′ N. to northern Brazil. In the eastern Atlantic the species is known from Madeira, the Cape Verde Islands, Morocco, and throughout the Gulf of Guinea south to South Africa. Depths of capture are from about 125 to 380 fathoms.

Genus **Ectreposebastes** Garman

Ectreposebastes GARMAN, 1899, p. 53 (type-species *Ectreposebastes imus* Garman, by monotypy). ESCHMEYER AND COLLETTE, 1966, pp. 366–367 (redefined genus; placed in subfamily Setarchinae; a single species occurring in the eastern Pacific and western and eastern Atlantic).

DIAGNOSIS. Dorsal rays usually XII, 9; anal rays usually III, 6 (2 spines in juveniles); pectoral rays 18–20; stomach often with some black pigment, but intestine and pyloric caeca pale; swimbladder absent or rudimentary; body soft and flabby in life.

Ectreposebastes imus Garman.

(See ESCHMEYER AND COLLETTE, 1966, pp. 367–371, fig. 4, for a detailed treatment.)

Ectreposebastes imus GARMAN, 1899, pp. 53–55, pls. 8, 9, and 71, fig. c (type locality Galápagos Islands, 384 fathoms, *Albatross* station 3403).

ADDITIONAL REFERENCE.

Ectreposebastes sp., BULLIS AND THOMPSON, 1965, p. 53 (*Oregon* station 1940; listed).

ADDITIONAL MATERIAL. UMML no. 22838 (1, 158) *Oregon* station 5233 and UMML no. 22839 (1, 65) *Oregon* station 5234, both from 29°54.5′ N., 80°10′ W., in 190 fathoms, 40-foot shrimp trawl.

DISTINGUISHING FEATURES. See this section under the account of *Setarches guentheri*.

DISTRIBUTION. Eschmeyer and Collette (1966) recorded this species from the eastern Pacific at the Galápagos Islands and off Peru, in the western Atlantic off the Mississippi Delta, Honduras, Colombia, and Puerto Rico, and in the

eastern Atlantic from Sierra Leone to Cameroun. The additional specimens listed above are the first from the Atlantic coast of the United States. Depths of capture range from about 150 to 400 fathoms, with some specimens taken in midwater trawls.

In a mimiographed United States Fish and Wildlife Service cruise report (23 May 1968) for *Townsend Cromwell* cruise 36, it was reported that a total of 223 specimens tentatively identified as *Ectreposebastes imus* were taken in two shrimp trawl hauls south of Honolulu, Hawaii, in 325–350 fathoms. Through correspondence with Paul J. Struhsaker, the identification has been verified. This amazing capture at Hawaii suggests that the species may be circumtropical in distribution and should be looked for in the western Pacific and Indian Ocean.

Speciation and Zoogeography of Atlantic Scorpionfishes

The scorpaenid fishes of the Atlantic Ocean belong for the most part to the more generalized subfamilies, and the majority of the species are referable to the subfamily Scorpaeninae. Most Atlantic species are in genera with a world-wide distribution, but some genera are restricted to the Atlantic.

The most primitive Atlantic scorpionfishes are in the subfamily Sebastinae, especially the genus *Sebastes* (following Matsubara's broad definition of the genus, 1943). The North Pacific appears to be the origin and center of speciation of *Sebastes*; the genus has not been successful in other areas. The family Scorpaenidae, represented mostly by species of *Sebastes*, contains more species than any other fish family occurring off California (Phillips, 1957, p. 9). Despite numerous species at this and more northern latitudes, crossing of the tropical region in the eastern Pacific has been difficult for these fishes. Jordan and Evermann (1898, pp. 1832–1833) thought that species of the genus *Sebastodes* (= *Sebastes*) would prove numerous in temperate waters off South America, but this has not proved to be so, and it is doubtful if more than a few species occur there. The single species *Sebastes capensis* in the South Atlantic (Tristan da Cunha and the southwest tip of South Africa) is closely related (doubtfully distinct) to *S. oculatus*, a species occurring from Chile to the Falkland Islands; the occurrence at Tristan da Cunha and South Africa apparently resulted from movement eastward with the prevailing currents. The presence of three species of the genus *Sebastes* in the extreme North Atlantic is most easily explained by a trans-Arctic movement. Two of the remaining genera of the subfamily Sebastinae, *Sebastiscus* and *Hozukius*, occur in the western Pacific; the genus *Helicolenus* is represented in all oceans.

The two species of the subfamily Setarchinae present in the Atlantic Ocean occur widely elsewhere. *Setarches guentheri* was treated (Eschmeyer and Collette, 1966) as occurring from Hawaii west to the western Atlantic. *Ectreposebastes imus* is known from the eastern Pacific, Hawaii, and both sides of the

Atlantic. Two additional species of this subfamily are confined to the Indo-West Pacific.

The remainder of the Atlantic scorpionfishes are treated as belonging to the subfamily Scorpaeninae. Several genera are represented in the Indo-Pacific and some are restricted to the Atlantic, but our knowledge of Indian Ocean scorpionfishes, particularly those living at deeper depths, is poor. Three genera occurring in the Atlantic are world-wide in distribution, *Scorpaenodes*, *Scorpaena*, and *Pontinus*; *Scorpaenodes* is best represented in the Indian and western Pacific oceans where the species are particularly common on reefs; *Scorpaena* and *Pontinus* are best represented in Atlantic and eastern Pacific waters. The genus *Phenacoscorpius* is known from one species in the western Atlantic and three species in the Indian and Pacific oceans. *Neomerinthe* (two in the western Atlantic and one tentatively included from the eastern Atlantic), *Trachyscorpia* (one common to both sides of the Atlantic and one at Tristan da Cunha) and *Idiastion*[3] (one western Atlantic species) are so far known only from the Atlantic. About five or six additional genera of the subfamily are not represented in the Atlantic Ocean.

In summary, the following species are represented on both sides of the Atlantic: *Setarches guentheri*, *Ectreposebastes imus*, *Helicolenus dactylopterus dactylopterus*, and *Trachyscorpia cristulata* (questionably as two subspecies).

The mid-Atlantic has been an effective barrier to species of the shallow-water tropical genera *Scorpaena* and *Scorpaenodes*. *Scorpaena plumieri* is unusual in occurring in the western Atlantic, at Saint Helena and Ascension, and in the eastern Pacific; *Scorpaena laevis* in the eastern Atlantic is closely related to *S. plumieri*. No other Atlantic species of *Scorpaena* appears to have a particularly close Atlantic relative in other than the same geographical area. Most of the eastern Atlantic species of the genus *Scorpaena* have ctenoid scales; exceptions are *S. laevis* derived from the *S. plumieri*-type, and *S. mellissii* from Saint Helena. The emarginate scales of *S. porcus* seem to be derived from ctenoid scales. Most Indian and western Pacific species also have ctenoid scales, while western Atlantic species all have cycloid scales. Among the eastern Atlantic species, one group has the pectoral-fin base, chest, and most of the head naked; some Indo-Pacific species share this character. A sub-group of eastern Atlantic species (*Scorpaena annobonae*, *S. azorica*, *S. loppei*, and *S. angolensis*) is unique in having the pores at the symphysis of the lower jaw united.

Some of the species of *Scorpaena* in the tropical and temperate eastern Pacific appear closely related to the western Atlantic species (for example, *Scorpaena russula* is closely related to the western Atlantic species *S. calcarata* and *S. inermis*; *S. plumieri* occurs in both areas). Other eastern Pacific species

[3] See Addendum.

have uncertain affinities, but the presence of cycloid scales favors relationship to western Atlantic species.

South Africa and the mid-Pacific have been effective barriers limiting the less generalized shallow-living, warm water scorpaenids of such groups as the subfamily Pteroinae, Apistinae, Minoinae, Pelorinae, and Synancejinae to the Indian and western Pacific oceans.

SUMMARY

The systematics of the fishes of the family Scorpaenidae occurring in the Atlantic Ocean are treated. Two new species of the genus *Scorpaena* and one new species of the genus *Pontinus* are described from the eastern Atlantic. One new subgenus of the genus *Trachyscorpia* is described and the species "*capensis*" Gmelin referred to it. *Pontinus pollux* Poey is thought to be a junior synonym of *P. castor* Poey; hence, *Neomerinthe hemingwayi* is reinstated as a valid species rather than a junior synonym of *P. pollux*. *Pontinus nematophthalmus* (Günther) replaces *P. macrolepis*. *Scorpaena folgori* Postel and Roux is not a species of *Scorpaena* and is referred to the genus *Neomerinthe*.

Besides one western Atlantic species of uncertain validity, 57 species in 11 genera occur in the Atlantic Ocean. The treatment of eastern Atlantic species is most complete for those species occurring in the Gulf of Guinea, but all eastern Atlantic species are included. Western Atlantic species receiving most attention are those not included in my previous papers. Species of the genus *Sebastes* occurring in the North Atlantic are not treated in detail, but *Sebastes capensis*, known from the South Atlantic, is included. Keys are provided for identification and some of the species are figured. Descriptions and synonymies are given. Information provided for species studied in my previous papers is abbreviated, but in some cases additional information is given. Also, in some cases information on species occurring in other oceans is included (for example, species of *Pontinus* and *Helicolenus*).

Speciation and zoogeography of Atlantic scorpionfishes are discussed.

ADDENDUM

After the manuscript was submitted, a collection from Angola was received including specimens of two species worthy of brief mention at this time. They were collected by George C. Miller on the U. S. Bureau of Commercial Fisheries vessel *Undaunted* and have been deposited in the collection of the California Academy of Sciences. The species of scorpionfishes occurring from Angola south to South Africa clearly deserve additional study.

Idiastion species.

Material examined. CAS no. 24401 (2, 77–86) off Angola, Kunene River transect, 17°18′S., 11°24′E., in 229–274 meters, *Undaunted* cruise 6801, station 68-266, 24 March 1968.

Remarks. These two specimens are the first of the genus *Idiastion* from the

eastern Atlantic. They are very similar to specimens of *Idiastion kyphos*, the western Atlantic species. Whether the eastern Atlantic specimens represent *I. kyphos* or whether they are a subspecies of *I. kyphos* or a new species, awaits a more thorough study. (The specimens "key" to the genus *Scorpaena* in part B of the key and to *Idiastion kyphos* in part A of the key.) The description of *I. kyphos* as given for the western Atlantic specimens fits the two eastern Atlantic specimens well. The pectoral rays in the two eastern Atlantic specimens number 18 and 19 rather than 17 and 18.

Scorpaena species.

MATERIAL EXAMINED. CAS no. 24426 (3, 174–186) off Angola, 16°20.2′S., 11°42.5′E., in 56 meters, *Undaunted* cruise 6801, station 68-249, 18 March 1968.

REMARKS. These three specimens appear to represent a new species closely related to *Scorpaena stephanica* and other species which have the pectoral-fin base and chest unscaled, the pores at the symphysis of the lower jaw separate, and scales on the flanks slightly ctenoid. The three specimens would be identified as *S. stephanica* in the key. They differ from *S. stephanica* mainly in coloration, but some morphological differences are also present. In body shape and some measurements (especially the short predorsal-fin length), the specimens resemble *S. angolensis*. In *S. angolensis* there is but a single pore at the symphysis of the lower jaw; in *Scorpaena* species the pores at the symphysis of the lower jaw are separated by about 1 or 2 pore diameters in two specimens and are almost united (probably not normal) in the third specimen. The occipital pit in the three specimens is deeper than in *S. stephanica* and about as deep as in *S. angolensis*. Both *S. stephanica* and *S. angolensis* were collected off Angola during the cruise which resulted in the collection of *Scorpaena* species.

The coloration of the specimens is as follows. Body and head mostly brownish above and lighter below. Anal fin, pelvic fins, and lower half of caudal fin with pale spots on a dusky background. Soft dorsal fin and upper half of caudal fin with brown spots. Spinous dorsal fin with a black patch between spines 6 or 7 to 9 or 10. Inside of pectoral fin also slightly dusky with paler large spots or with light brown spots surrounded by whitish ring on a more dusky background.

Counts and measurements (in percent standard length) are as follows: Dorsal rays XII,9 (one with XII,7); anal rays III,5; pectoral rays 18; vertical scale rows about 40–45; gill rakers 5 + 9–11, including rudiments. Head length 43–44 percent; body depth 32–33; orbit diameter 10; snout length 11–12; interorbital width 4.4–5.6; jaw length 19–21; predorsal-fin length 31–33; pectoral fin length 33–36; pelvic fin length 25–28, fin reaching to about first anal spine; caudal fin length 31–36.

Scorpaena species is not likely to be *Scorpaena gaillardae* Roux, which is here treated as a synonym of *S. stephanica*. *Scorpaena* species appears to differ from *S. stephanica* (including *S. gaillardae*) in having a shorter pectoral fin, shorter predorsal-fin length, deeper occipital pit, different coloration (especially on the

pectoral, pelvic, anal, and caudal fins), black spot on the spinous dorsal fin at midheight of fin membranes rather than on the distal two-thirds. Roux (1957) did not report *S. stephanica* from off the coast of Africa (near Point Noire), but on the basis of my material it should be common there; this also favors the view that *S. gaillardae* is a synonym of *S. stephanica*. Roux (1957) mentions a crest on the maxillary in *S. gaillardae*; he probably was referring to the shallow crest which occurs in *S. stephanica* and some other species, including *Scorpaena* species.

Table 1. *Frequency distributions of number of dorsal rays in Atlantic scorpionfishes of the subfamilies Scorpaeninae and Setarchinae.*

	Spines				*Soft rays*[1]				
Species	*11*	*12*	*13*	*14*	*7*	*8*	*9*	*10*	*11*
Pontinus longispinis									
Northern population	—	47	—	—	—	—	46	1	—
Southern population	—	49	—	—	—	—	49	—	—
P. helena	—	2	—	—	—	—	1	1	—
P. castor	—	12	—	—	—	—	1	10	—
P. nematophthalmus	—	61	—	—	—	4	57	—	—
P. rathbuni	1	40	—	—	—	2	38	—	—
P. accraensis	2	66	—	—	—	1	67	—	—
P. leda	—	27	1	—	—	1	27	—	—
P. kuhlii	—	9	—	—	—	—	9	—	—
P. nigropunctatus	—	2	—	—	—	—	2	—	—
Neomerinthe hemingwayi	—	34	—	—	—	—	1	33	—
N. beanorum	—	61	—	—	—	4	57	—	—
N. folgori[2]	—	2	—	—	—	—	—	—	2
Trachyscorpia cristulata									
Western Atlantic	—	20	—	—	—	2	18	—	—
Eastern Atlantic[3]	—	xx	—	—	—	4	5	—	—
T. capensis[4]	—	—	1	—	—	x	1	—	—
Idiastion kyphos	—	2	—	—	—	—	2	—	—
Phenacoscorpius nebris	—	10	—	—	—	—	10	—	—
Scorpaena petricola	—	12	—	—	—	—	12	—	—
S. melasma	—	2	—	—	—	—	2	—	—
S. brachyptera	—	12	—	—	1	10	1	—	—
S. elachys	—	14	—	—	—	3	11	—	—
S. grandicornis	—	37	—	—	—	—	38	—	—
S. brasiliensis	—	32	3	—	—	1	32	—	—
S. bergii	—	21	—	—	—	—	21	—	—
S. isthmensis	2	48	—	—	—	—	50	—	1
S. albifimbria	—	9	—	—	—	2	7	—	—
S. inermis	—	16	—	—	3	13	—	—	—
S. calcarata	—	53	—	—	1	3	48	1	—
S. dispar	—	43	—	—	—	2	41	—	—
S. agassizii	1	50	—	—	—	1	50	—	—
S. plumieri									
Western Atlantic	—	28	—	—	—	—	28	—	—
Central Atlantic	—	2	—	—	—	—	2	—	—

TABLE 1. (*Continued*)

Species	Spines				Soft rays[1]				
	11	12	13	14	7	8	9	10	11
S. normani	—	39	—	—	—	1	37	1	—
S. angolensis	—	26	—	—	—	—	26	—	—
S. stephanica	—	31	—	—	—	1	30	—	—
S. elongata	—	8	—	—	—	2	6	—	—
S. scrofa	—	11	—	—	—	—	11	—	—
S. laevis	—	14	—	—	—	—	14	—	—
S. loppei	—	2	—	—	—	—	2	—	—
S. annobonae	—	1	—	—	—	—	—	1	—
S. azorica	—	1	—	—	—	—	1	—	—
S. maderensis	—	11	—	—	—	—	11	—	—
S. canariensis[5]	—	1	—	—	—	—	1	—	—
S. mellissii	—	1	—	—	—	—	1	—	—
S. notata[6]	—	19	—	—	—	—	19	—	—
S. porcus	—	21	—	—	—	—	21	—	—
Scorpaenodes caribbaeus	—	—	23	1	—	—	24	—	—
S. tredecimspinosus	—	—	30	—	—	6	24	—	—
S. africanus	—	—	6	—	—	1	5	—	—
S. arenai[7]	—	—	5	—	—	—	5	—	—
S. elongatus[8]	—	—	1	2	—	—	2	1	—
Setarches guentheri									
Western Atlantic	—	66	—	—	—	19	47	—	—
Eastern Atlantic	3	63	3	—	—	25	48	—	—
Ectreposebastes imus[9]	—	36	—	—	—	—	5	32	—

[1] Last double
[2] Includes holotype, Postel and Roux, 1964.
[3] From Boutiere, 1958.
[4] Smith (1949) gives soft rays as 8–9.
[5] From Cadenat, 1945.
[6] One with 9 spines and 7 soft rays.
[7] From Torchio, 1962.
[8] From Cadenat (1959) in part.
[9] Includes eastern Pacific.

TABLE 2. *Frequency distributions of number of pectoral rays (left side) in Atlantic scorpionfishes of the subfamily Scorpaeninae.*[1]

Species	Pectoral rays									
	15	16	17	18	19	20	21	22	23	24
Pontinus longispinis										
Northern population	—	6	177	9	—	—	—	—	—	—
Southern population	—	—	26	23	—	—	—	—	—	—
P. helena	—	—	—	—	1	1[9]	—	—	—	—
P. castor	—	—	15	—	—	—	—	—	—	—
P. nematophthalmus	3	67[10]	1	—	—	—	—	—	—	—
P. rathbuni	—	1	58	5	—	—	—	—	—	—
P. accraensis	—	6	128	5	—	—	—	—	—	—
P. leda	—	—	5	23	—	—	—	—	—	—
P. kuhlii	—	—	8	1	—	—	—	—	—	—
P. nigropunctatus	—	—	—	2	—	—	—	—	—	—
Neomerinthe hemingwayi	—	5[11]	44	—	—	—	—	—	—	—
N. beanorum	—	2	64	1	—	—	—	—	—	—

Table 2. (*Continued*)

Species	Pectoral rays 15	16	17	18	19	20	21	22	23	24
N. folgori[2]	—	—	2	—	—	—	—	—	—	—
Trachyscorpia cristulata										
Western Atlantic	—	—	—	—	—	—	—	3[12]	26	5
Eastern Atlantic[3]	—	—	—	—	—	—	3	6	1	—
T. capensis[4]	—	—	—	—	—	x	x	x	x	—
Idiastion kyphos	—	—	1	1	—	—	—	—	—	—
Phenacoscorpius nebris	—	8	2	—	—	—	—	—	—	—
Scorpaena petricola	—	—	2	10	—	—	—	—	—	—
S. melasma	—	—	—	—	—	—	2	—	—	—
S. brachyptera	—	—	—	—	6	8	—	—	—	—
S. elachys	—	3	11	—	—	—	—	—	—	—
S. grandicornis	—	—	4	76	11	—	—	—	—	—
S. brasiliensis	—	1[14]	1	16	122	19	—	—	—	—
S. bergii	—	6	44	—	—	—	—	—	—	—
S. isthmensis	—	1	2	44	3	—	—	—	—	—
S. albifimbria	—	—	—	—	6	13	2	—	—	—
S. inermis	—	—	—	—	5	22	1	—	—	—
S. calcarata	—	—	—	1	31	171	32	—	—	—
S. dispar[5]	—	—	13	30	11	—	—	—	—	—
S. agassizii	—	—	—	1	12	120	13	—	—	—
S. plumieri										
Western Atlantic	—	—	—	2	45	44	5	—	—	—
Central Atlantic	—	—	—	—	—	2	2	—	—	—
S. normani	—	—	—	3	32	5	—	—	—	—
S. angolensis	—	—	2	24	—	—	—	—	—	—
S. stephanica	—	—	1	26	2	—	—	—	—	—
S. elongata	—	—	—	1	6	—	—	—	—	—
S. scrofa	—	—	—	2[9]	8	1[9]	—	—	—	—
S. laevis	—	—	—	1[9]	8	3	—	—	—	—
S. loppei	—	—	—	2[13]	—	—	—	—	—	—
S. annobonae	—	—	—	1	—	—	—	—	—	—
S. azorica	—	—	—	1	—	—	—	—	—	—
S. maderensis	5	6[13]	—	—	—	—	—	—	—	—
S. canariensis[6]	—	1	—	—	—	—	—	—	—	—
S. mellissii	—	—	—	—	—	1	—	—	—	—
S. notata	—	—	1	19[13]	—	—	—	—	—	—
S. porcus	—	9	12	—	—	—	—	—	—	—
Scorpaenodes caribbaeus	—	—	—	17	60	4	—	—	—	—
S. tredecimspinosus	—	4	24	2	—	—	—	—	—	—
S. africanus	—	—	1	3	1	—	—	—	—	—
S. arenai[7]	—	—	x	x	x	—	—	—	—	—
S. elongatus[8]	—	—	—	2	1	—	—	—	—	—

1 Counts by Ginsburg (1953, p. 14) for western Atlantic species included.
2 Includes holotype, Postel and Roux, 1964.
3 From Boutiere, 1958.
4 From Smith, 1949.
5 One with 14 on left and 18 on right.
6 From Cadenat, 1945.
7 From Torchio, 1962.
8 From Cadenat (1949) in part.
9 19 on right side.
10 16 on right side.
11 3 with 17 on right.
12 1 with 21 on right.
13 18 on right.
14 1 with 17 on right.

TABLE 3. *Frequency distributions of orbit diameter expressed as percent standard length in available Atlantic scorpionfishes of the subfamily Scorpaeninae, except western Atlantic species of the genus* Scorpaena.[1]

Species	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*Size range mm S. L.*
Pontinus longispinis										
Northern population	—	—	—	1	26	15	4	1	—	31–171
Southern population	—	—	1	3	8	18	12	3	2	52–205
P. helena	—	—	—	—	1	1	—	—	—	186–203
P. castor	—	—	1	3	6	2	—	—	—	25–256
P. nematophthalmus	—	—	—	—	3	21	14	10	2	29–132
P. rathbuni	—	—	—	4	7	17	10	2	—	38–197
P. accraensis	—	—	—	4	16	33	69	13	3	50–170
P. leda	—	—	—	—	—	7	14	6	1	71–163
P. kuhlii	—	—	5	2	—	1	—	—	—	146–230
P. nigropunctatus	—	1	—	1	—	—	—	—	—	193–272
Neomerinthe hemingwayi	2	16	13	2	—	—	—	—	—	102–315
N. beanorum	—	—	2	6	7	11	9	—	—	33–154
N. folgori	—	1	—	—	—	—	—	—	—	340
Trachyscorpia cristulata[2]	—	—	—	1	2	7	5	2	3	62–352
T. capensis	—	—	—	—	—	1	—	—	—	320
Idiastion kyphos	—	—	—	—	—	—	1	1	—	53–105
Phenacoscorpius nebris	—	—	—	—	—	2	1	—	—	46–84
Scorpaena normani	—	—	—	—	3	12	9	1	—	47–124
S. angolensis	—	—	—	6	8	10	2	—	—	59–137
S. stephanica	—	1	7	9	9	4	1	1	—	60–225
S. elongata	—	—	4	3	1	—	—	—	—	145–255
S. scrofa	—	1	6	—	—	—	—	—	—	96–211
S. laevis	—	5	4	5	—	—	—	—	—	28–220
S. loppei	—	—	—	—	1	1	—	—	—	55–59
S. annobonae	—	—	—	—	—	—	1	—	—	44
S. azorica	—	—	—	1	—	—	—	—	—	98
S. maderensis	—	—	1	4	2	—	—	—	—	41–96
S. mellissii	—	1	—	—	—	—	—	—	—	202
S. notata	—	—	—	2	1	4	2	—	—	62–115
S. porcus	—	—	—	2	3	6	—	—	—	39–102
Scorpaenodes caribbaeus	—	—	—	—	4	5	5	7	—	35–82
S. tredecimspinosus	—	—	—	—	2	1	6	3	—	24–45
S. africanus	—	—	—	—	—	2	1	1	1	33–50
S. elongatus	—	—	—	1	—	—	—	—	—	88
S. arenai[3]	—	—	1	—	3	1	—	—	—	52–75

[1] Larger specimens tend to have proportionally smaller orbits.
[2] Western Atlantic only.
[3] Calculated from data given by Torchio (1962, p. 115).

Table 4. *Frequency distributions of snout length expressed as percent standard length in Atlantic scorpionfishes of the subfamily Scorpaeninae, except western Atlantic species of the genus* Scorpaena.[1]

Species	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*
Pontinus longispinis									
Northern population	—	1	17	20	9	—	—	—	—
Southern population	1	2	14	18	11	2	—	—	—
P. helena	—	—	—	—	—	2	—	—	—
P. castor	—	—	—	—	2	8	1	—	1
P. nematophthalmus	—	1	16	30	3	—	—	—	—
P. rathbuni	—	—	16	21	2	1	—	—	—
P. accraensis	—	1	15	59	33	24	3	—	—
P. leda	—	3	16	7	2	—	—	—	—
P. kuhlii	—	—	—	3	4	1	—	—	—
P. nigropunctatus	—	—	—	—	—	1	—	—	—
Neomerinthe hemingwayi	—	—	—	1	18	14	—	—	—
N. beanorum	—	—	—	6	26	5	1	—	—
N. folgori	—	—	—	—	—	—	—	1	—
Trachyscorpia cristulata[2]	—	7	13	—	—	—	—	—	—
T. capensis	1	—	—	—	—	—	—	—	—
Idiastion kyphos	—	—	1	1	—	—	—	—	—
Phenacoscorpius nebris	—	—	—	1	—	2	—	—	—
Scorpaena normani	—	15	9	1	—	—	—	—	—
S. angolensis	—	18	8	—	—	—	—	—	—
S. stephanica	—	7	18	7	—	—	—	—	—
S. elongata	—	—	1	4	3	—	—	—	—
S. scrofa	—	—	—	2	5	—	—	—	—
S. laevis	—	5	7	2	—	—	—	—	—
S. plumieri	—	—	—	1	3	—	—	—	—
S. loppei	—	1	1	—	—	—	—	—	—
S. annobonae	—	—	—	—	1	—	—	—	—
S. azorica	—	1	—	—	—	—	—	—	—
S. maderensis	—	—	3	4	—	—	—	—	—
S. mellissii	—	—	—	—	1	—	—	—	—
S. notata	—	2	7	—	—	—	—	—	—
S. porcus	1	5	4	—	—	—	—	—	—
Scorpaenodes caribbaeus	—	8	11	1	—	—	—	—	—
S. tredecimspinosus	4	6	2	—	—	—	—	—	—
S. africanus	—	3	1	1	—	—	—	—	—
S. elongatus	—	—	—	—	1	—	—	—	—
S. arenai[3]	—	—	3	2	—	—	—	—	—

[1] Size ranges of specimens measured as in table 3.
[2] Western Atlantic specimens only.
[3] Calculated from data given by Torchio (1962, p. 115).

TABLE 5. *Frequency distributions of head length expressed as percent standard length in available Atlantic scorpionfishes of the subfamily Scorpaeninae, except western Atlantic species of the genus* Scorpaena.[1, 2]

Species	*40*	*41*	*42*	*43*	*44*	*45*	*46*	*47*	*48*	*49*	*50*	*51*
Pontinus longispinis												
Northern population	2	5	16	14	6	4	—	—	—	—	—	—
Southern population	—	—	1	5	8	12	13	3	5	—	—	—
P. helena	—	—	—	—	—	—	—	—	1	1	—	—
P. castor	—	—	—	—	—	1	1	5	1	2	—	1
P. nematophthalmus	—	—	—	—	8	8	12	13	6	2	—	—
P. rathbuni	—	—	2	2	11	12	9	3	1	—	—	—
P. accarensis	—	—	—	2	12	19	43	28	24	7	—	—
P. leda	—	—	—	—	2	2	2	4	8	2	6	2
P. kuhlii	—	—	—	—	—	5	2	—	1	—	—	—
P. nigropunctatus	—	—	—	—	—	1	—	1	—	—	—	—
Neomerinthe hemingwayi	—	—	1	—	8	13	8	2	1	—	—	—
N. beanorum	—	—	—	—	1	1	11	6	10	8	1	—
N. folgori	—	—	—	—	—	—	—	—	—	1	—	—
Trachyscorpia cristulata[3]	—	—	—	—	—	—	2	3	10	5	—	—
T. capensis	—	—	—	—	1	—	—	—	—	—	—	—
Idiastion kyphos	—	—	—	—	—	—	1	—	1	—	—	—
Phenacoscorpius nebris	—	—	—	—	—	—	2	—	1	—	—	—
Scorpaena normani	—	2	4	12	2	5	—	—	—	—	—	—
S. angolensis	—	—	3	7	8	5	3	—	—	—	—	—
S. elongata	—	—	—	—	—	4	2	2	—	—	—	—
S. stephanica	—	—	3	9	8	9	2	1	—	—	—	—
S. scrofa	—	—	—	—	2	2	2	1	—	—	—	—
S. laevis	—	—	—	4	1	6	2	1	—	—	—	—
S. loppei	—	—	—	—	2	—	—	—	—	—	—	—
S. annobonae	—	—	—	—	—	—	—	—	1	—	—	—
S. azorica	—	1	—	—	—	—	—	—	—	—	—	—
S. maderensis	1	3	2	1	—	—	—	—	—	—	—	—
S. mellissii	—	—	1	—	—	—	—	—	—	—	—	—
S. notata	—	1	1	3	3	1	—	—	—	—	—	—
S. porcus	—	—	—	2	3	2	2	1	—	—	—	—
Scorpaenodes caribbaeus	—	—	1	3	5	7	4	1	—	—	—	—
S. tredecimspinosus	1	2	4	3	2	—	—	—	—	—	—	—
S. africanus	—	—	1	1	2	—	1	—	—	—	—	—
S. elongatus	—	—	—	1	—	—	—	—	—	—	—	—
S. arenai[4]	—	1	1	2	1	—	—	—	—	—	—	—

1 Larger specimens tend to have proportionally smaller heads.
2 Size range as in table 3.
3 Western Atlantic only.
4 From Torchio (1962, p. 115).

Table 6. *Frequency distributions of body depth expressed as percent standard length in Atlantic scorpionfishes of the subfamily Scorpaeninae, except western Atlantic species of the genus* Scorpaena.[1]

Species	*28*	*29*	*30*	*31*	*32*	*33*	*34*	*35*	*36*	*37*	*38*	*39*	*40*	*41*
Pontinus longispinis														
Northern population	—	5	14	14	10	3	1	—	—	—	—	—	—	—
Southern population	1	1	10	9	21	4	1	—	—	—	—	—	—	—
P. helena	—	—	—	—	—	—	—	1	—	1	—	—	—	—
P. castor	—	—	—	1	5	2	3	—	—	—	—	—	—	—
P. nematophthalmus	—	—	—	1	4	9	8	13	11	3	1	—	—	—
P. rathbuni	—	—	1	2	4	7	12	5	6	1	2	—	—	—
P. accraensis	—	—	—	3	17	17	20	10	3	—	—	—	—	—
P. leda	—	—	—	—	1	—	5	4	2	8	5	3	—	—
P. kuhlii	—	—	—	—	—	—	1	4	2	1	—	—	—	—
P. nigropunctatus	—	—	—	—	—	1	—	1	—	—	—	—	—	—
Neomerinthe hemingwayi	3	6	7	9	5	1	—	—	—	—	—	—	—	—
N. beanorum	—	2	11	12	7	5	—	—	—	—	—	—	—	—
N. folgori	—	—	—	—	—	—	—	—	—	—	1	—	—	—
Trachyscorpia cristulata[2]	—	—	—	—	1	2	11	4	2	—	—	—	—	—
T. capensis	—	—	—	—	—	1	—	—	—	—	—	—	—	—
Idiastion kyphos	—	—	—	—	—	—	—	—	—	—	1	1	—	—
Phenacoscorpius nebris	—	—	—	—	—	—	—	1	—	1	—	—	1	—
Scorpaena normani	—	—	—	—	—	—	3	8	7	1	5	1	—	—
S. angolensis	—	—	—	—	—	3	5	7	4	3	4	—	—	—
S. elongata	—	—	—	1	4	1	1	1	—	—	—	—	—	—
S. stephanica	—	—	3	—	4	7	9	2	3	1	—	—	—	—
S. scrofa	—	—	—	—	—	—	1	1	2	1	1	1	—	—
S. laevis	—	—	—	—	—	1	4	2	2	1	3	—	—	—
S. loppei	—	—	—	—	—	1	—	—	—	1	—	—	—	—
S. annobonae	—	—	—	—	—	—	—	—	—	—	—	—	—	1
S. azorica	—	—	—	—	—	—	—	—	—	1	—	—	—	—
S. maderensis	—	—	—	—	—	1	3	2	—	—	1	—	—	—
S. mellissii	—	—	—	1	—	—	—	—	—	—	—	—	—	—
S. notata	—	—	—	—	—	—	—	—	—	2	2	3	1	1
S. porcus	—	—	—	—	—	—	—	—	1	1	3	3	1	1
Scorpaenodes caribbaeus	—	—	—	—	—	—	—	3	6	7	2	1	2	—
S. tredecimspinosus	—	—	—	—	—	—	1	1	4	2	2	1	1	—
S. africanus	—	—	—	—	—	—	1	1	1	—	1	1	—	—
S. elongatus	—	—	1	—	—	—	—	—	—	—	—	—	—	—
S. arenai[3]	—	—	—	—	1	—	—	1	1	—	—	2	—	—

[1] Size range as in table 3.
[2] Western Atlantic only.
[3] Calculated from data given by Torchio (1962: 115).

TABLE 7. *Frequency distributions of interorbital width expressed as percent standard length in Atlantic scorpionfishes of the subfamily Scorpaeninae, except western Atlantic species of the genus* Scorpaena.[1]

Species	*2.6–3.0*	*3.1–3.5*	*3.6–4.0*	*4.1–4.5*	*4.6–5.0*	*5.1–5.5*	*5.6–6.0*	*6.1–6.5*	*6.6–7.0*	*7.1–7.5*	*7.6–8.0*	*8.1–8.5*	*8.6–9.0*	*9.1–9.5*
Pontinus longispinis														
Northern population	—	1	21	21	4	—	—	—	—	—	—	—	—	—
Southern population	—	4	27	16	—	—	—	—	—	—	—	—	—	—
P. helena	—	—	—	—	2	—	—	—	—	—	—	—	—	—
P. castor	—	4	5	3	—	—	—	—	—	—	—	—	—	—
P. nematophthalmus	—	—	20	26	4	—	—	—	—	—	—	—	—	—
P. rathbuni	—	3	19	17	1	—	—	—	—	—	—	—	—	—
P. accraensis	—	1	29	37	2	—	—	—	—	—	—	—	—	—
P. leda	—	—	1	8	18	2	—	—	—	—	—	—	—	—
P. kuhlii	—	—	5	3	—	—	—	—	—	—	—	—	—	—
P. nigropunctatus	—	—	—	—	2	—	—	—	—	—	—	—	—	—
Neomerinthe hemingwayi	—	—	—	—	15	17	1	—	—	—	—	—	—	—
N. beanorum	—	—	5	24	9	—	—	—	—	—	—	—	—	—
N. folgori	—	—	—	—	—	1	—	—	—	—	—	—	—	—
Trachyscorpia cristulata[2]	—	—	—	1	5	7	4	3	—	—	—	—	—	—
T. capensis	1	—	—	—	—	—	—	—	—	—	—	—	—	—
Idiastion kyphos	—	—	—	—	—	1	1	—	—	—	—	—	—	—
Phenacoscorpius nebris	—	—	1	—	1	1	—	—	—	—	—	—	—	—
Scorpaena normani	—	—	—	—	—	—	6	10	7	2	—	—	—	—
S. angolensis	—	—	—	—	1	11	13	2	—	—	—	—	—	—
S. stephanica	—	—	—	—	1	8	13	4	3	1	—	—	—	—
S. elongata	—	—	—	—	—	1	3	4	—	—	—	—	—	—
S. scrofa	—	—	—	—	—	1	2	4	—	—	—	—	—	—
Scorpaena laevis	—	—	—	—	—	—	—	—	3	4	1	1	4	1
S. plumieri[3]	—	—	—	—	—	—	—	—	1	1	2	—	—	—
S. loppei	—	—	—	—	—	—	—	2	—	—	—	—	—	—
S. annobonae	—	—	—	—	—	—	1	—	—	—	—	—	—	—
S. azorica	—	—	—	—	—	—	1	—	—	—	—	—	—	—
S. maderensis	—	—	—	3	4	—	—	—	—	—	—	—	—	—
S. mellissii	—	—	—	—	1	—	—	—	—	—	—	—	—	—
S. notata	—	—	—	—	5	1	3	—	—	—	—	—	—	—
S. porcus	—	—	—	—	—	2	2	4	1	—	1	—	—	—
Scorpaenodes caribbaeus	—	—	—	—	—	4	10	7	—	—	—	—	—	—
S. tredecimspinosus	—	—	—	1	1	5	2	3	—	—	—	—	—	—
S. africanus	—	—	—	—	3	2	—	—	—	—	—	—	—	—
S. elongatus	—	—	—	—	—	—	—	1	—	—	—	—	—	—

[1] Size range as in table 3.
[2] Western Atlantic only; larger specimens with higher values.
[3] Saint Helena and Ascension only.

Table 8. *Frequency distributions of jaw length expressed as percent standard length in Atlantic scorpionfishes of the subfamily Scorpaeninae, except western Atlantic species of the genus* Scorpaena.[1]

Species	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*	*27*
Pontinus longispinis									
Northern population	7	29	11	—	—	—	—	—	—
Southern population	—	—	10	30	2	—	—	—	—
P. helena	—	—	—	—	1	—	1	—	—
P. castor	—	—	—	6	6	—	—	—	—
P. nematophthalmus	—	—	3	25	15	6	—	—	—
P. rathbuni	1	7	15	14	3	—	—	—	—
P. accraensis	—	—	—	13	21	13	1	—	—
P. leda	—	—	—	1	4	6	5	11	1
P. kuhlii	—	—	1	6	1	—	—	—	—
P. nigropunctatus	—	—	—	—	1	—	—	—	—
Neomerinthe hemingwayi	—	10	18	5	—	—	—	—	—
N. beanorum	—	3	7	11	6	1	—	—	—
N. folgori	—	—	—	—	1	—	—	—	—
Trachyscorpia cristulata[2]	—	—	—	3	13	4	—	—	—
T. capensis	—	—	—	1	—	—	—	—	—
Idiastion kyphos	—	—	—	1	—	1	—	—	—
Phenacoscorpius nebris	—	—	—	1	2	—	—	—	—
Scorpaena normani	—	1	9	14	1	—	—	—	—
S. angolensis	1	8	10	6	1	—	—	—	—
S. stephanica	—	1	4	15	7	4	—	—	—
S. elongata	—	—	—	6	2	—	—	—	—
S. scrofa	—	—	1	4	2	—	—	—	—
S. laevis	1	4	6	3	—	—	—	—	—
S. plumieri[3]	—	—	—	2	1	—	—	—	—
S. loppei	—	—	—	1	—	1	—	—	—
S. annobonae	—	—	—	—	—	—	1	—	—
S. azorica	1	—	—	—	—	—	—	—	—
S. maderensis	—	2	3	1	1	—	—	—	—
S. mellissii	—	—	—	1	—	—	—	—	—
S. notata	—	3	4	2	—	—	—	—	—
S. porcus	—	3	4	3	—	—	—	—	—
Scorpaenodes caribbaeus	—	—	—	5	8	8	—	—	—
S. tredecimspinosus	—	—	—	—	—	4	3	4	1
S. africanus	—	—	—	1	1	1	2	—	—
S. elongatus	—	1	—	—	—	—	—	—	—

[1] Size ranges as in table 3.
[2] Western Atlantic specimens only.
[3] Saint Helena and Ascension only.

TABLE 9. *Frequency distributions of predorsal-fin length expressed as percent standard length in Atlantic scorpionfishes of the subfamily Scorpaeninae, except western Atlantic species of the genus* Scorpaena.[1]

Species	*32*	*33*	*34*	*35*	*36*	*37*	*38*	*39*	*40*	*41*	*42*	*43*	*44*	*45*	*46*	*47*
Pontinus longispinis																
Northern population	—	—	—	—	—	2	14	22	4	3	1	—	—	—	—	—
Southern population	—	—	—	—	—	—	6	4	12	16	6	4	—	—	—	—
P. helena	—	—	—	—	—	—	—	—	—	—	1	—	1	—	—	—
P. castor	—	—	—	—	—	—	—	—	—	—	4	4	1	2	1	—
P. nematophthalmus	—	—	—	—	—	1	8	9	9	12	7	2	1	—	—	—
P. rathbuni	—	—	—	—	1	3	8	8	11	6	3	—	—	—	—	—
P. accraensis	—	—	—	—	—	2	5	6	20	25	7	5	—	—	—	—
P. leda	—	—	—	—	—	—	1	2	1	6	5	9	3	—	—	—
P. kuhlii	—	—	—	—	—	—	—	2	2	1	3	—	—	—	—	—
P. nigropunctatus	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—
Neomerinthe hemingwayi	—	—	—	—	—	—	3	9	15	6	—	—	—	—	—	—
N. beanorum	—	—	—	—	—	—	—	1	3	4	12	7	1	—	—	—
N. folgori	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—
Trachyscorpia cristulata[2]	—	—	—	—	—	—	—	—	—	1	3	9	6	—	1	—
T. capensis	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—
Idiastion kyphos	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
Phenacoscorpius nebris	—	—	—	—	—	—	—	—	1	—	—	1	1	—	—	—
Scorpaena normani	—	2	3	4	5	6	4	—	1	—	—	—	—	—	—	—
S. angolensis	1	4	6	5	6	4	—	—	—	—	—	—	—	—	—	—
S. stephanica	—	—	—	4	9	7	8	3	—	—	—	—	—	—	—	—
S. elongata	—	—	—	—	—	—	3	3	2	—	—	—	—	—	—	—
S. scrofa	—	—	—	—	—	—	3	2	2	—	—	—	—	—	—	—
S. laevis	—	—	—	—	8	2	3	1	—	—	—	—	—	—	—	—
S. plumieri[3]	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—
S. loppei	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—
S. annobonae	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—
S. azorica	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
S. maderensis	—	—	1	1	4	1	—	—	—	—	—	—	—	—	—	—
S. notata	—	—	1	—	2	3	3	—	—	—	—	—	—	—	—	—
S. porcus	—	—	—	—	1	3	3	1	1	1	—	—	—	—	—	—
Scorpaenodes caribbaeus	—	—	—	—	—	—	—	—	—	5	5	5	4	2	—	—
S. tredecimspinosus	—	—	—	—	—	—	1	—	3	3	4	1	—	—	—	—
S. africanus	—	—	—	—	—	—	—	—	1	1	1	1	1	—	—	—
S. elongatus	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—

[1] Size ranges as in table 3.
[2] Western Atlantic specimens only.
[3] Saint Helena and Ascension.

Table 10. *Frequency distributions of total gill rakers including rudiments on the first arch of central and eastern Atlantic scorpionfishes of the subfamily Scorpaeninae.*

Species	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*
Pontinus accraensis[1]	—	—	—	—	6	14	26	6	—	—
P. leda[1]	—	—	—	—	1	9	9	4	1	—
P. kuhlii[1]	—	—	—	—	—	—	2	4	2	1
P. nigropunctatus[1]	—	—	—	—	—	1	1	—	—	—
Neomerinthe folgori[1]	—	—	—	—	—	—	—	1	—	—
Scorpaena normani	—	—	1	13	7	3	—	—	—	—
S. angolensis	—	3	11	4	3	—	—	—	—	—
S. stephanica	—	—	3	14	4	3	—	—	—	—
S. elongata	1	—	2	2	—	—	—	—	—	—
S. scrofa	—	1	3	6	—	—	—	—	—	—
S. laevis	1	8	2	—	—	—	—	—	—	—
S. plumieri	—	1	—	—	—	—	—	—	—	—
S. loppei	—	1	—	1	—	—	—	—	—	—
S. annobonae	—	1	—	—	—	—	—	—	—	—
S. azorica	—	—	1	1	—	—	—	—	—	—
S. maderensis	—	—	2	5	3	1	—	—	—	—
S. mellissii	—	—	1	—	—	—	—	—	—	—
S. notata	—	1	1	12	2	2	—	—	—	—
S. porcus	—	—	—	1	9	12	—	—	—	—
Scorpaenodes africanus[1]	—	—	1	2	2	—	—	—	—	—

[1] Rudiments on hypobranchial frequently difficult to count.

Table 11. *Frequency distributions of number of dorsal rays and pectoral rays in specimens of* Helicolenus dactylopterus *from the Atlantic Ocean.*

	Dorsal spines			*Dorsal soft rays*					*Pectoral rays*			
	11	*12*	*13*	*10*	*11*	*12*	*13*	*14*	*17*	*18*	*19*	*20*
Helicolenus d. dactylopterus												
Northern Atlantic												
Eschmeyer	—	9	—	—	—	8	1	—	—	1	8	—
Ginsburg, 1953	—	7	—	—	—	7	—	—	—	—	6	1
Boutiere, 1958	—	—	—	—	10	151	18	1	—	8	79	6
Ben-Tuvia, 1962	—	9	2	—	3	8	—	—	—	—	—	—
Gulf of Guinea	—	38	1	—	4	33	2	—	—	—	25	13
South Africa[1]	—	2	—	—	—	2	x[1]	—	—	—	2	x[1]
Northwestern Atlantic												
Eschmeyer	—	80	—	—	8	69	2	—	1[3]	1	77[4]	—
Ginsburg, 1953	2	174	4	1	28	144	6	—	2	29	142	8
Eschmeyer (Venezuela)	—	6	—	—	—	5	1	—	—	3	3	—
Helicolenus d. lahillei												
Ginsburg, 1953[2]	—	8	1	—	1	7	1	—	—	1	8	—

[1] J. L. B. Smith (1949) gives dorsal rays as XII, 12–13; pectoral rays as 19, rarely 20.
[2] I have re-examined 5 of these specimens.
[3] 19 on right.
[4] 18 on right in some specimens.

TABLE 12. *Frequency distributions of number of gill rakers in specimens of* Helicolenus dactylopterus *from the Atlantic Ocean.*

	Upper arch			*Lower arch*						*Total*							
	7	*8*	*9*	*16*	*17*	*18*	*19*	*20*	*21*	*23*	*24*	*25*	*26*	*27*	*28*	*29*	*30*
Helicolenus d. dactylopterus																	
Northeastern Atlantic[1]																	
Eschmeyer	6	3	—	—	5	4	—	—	—	—	5	1	3	—	—	—	—
Ginsburg, 1953	6	1	—	1	3	3	—	—	—	1	3	2	1	—	—	—	—
Gulf of Guinea	—	15	12	—	4	19	4	—	—	—	—	1	15	9	2	—	—
South Africa[2]	—	—	2	—	—	—	x	1	1	—	—	—	—	—	—	1	1
Northwestern Atlantic																	
Eschmeyer	25	47	—	1	47	24	—	—	—	1	18	35	18	—	—	—	—
Ginsburg, 1953	58	60	5	7	66	50	—	—	—	6	38	43	32	4	—	—	—
Eschmeyer (Venezuela)	2	4	—	1	4	1	—	—	—	1	1	3	1	—	—	—	—
Helicolenus d. lahillei																	
Southwestern Atlantic	—	4	1	—	—	2	3	—	—	—	—	—	2	2	1	—	—

[1] Boutiere (1958) gives gill rakers as 12 or 13 on the lower arch, but he counted only the ceratobranchial; this would be equivalent to about 17 or 18 on the lower arch.
[2] Smith (1957b) lists gill rakers as 8 + 1, 19–20.

TABLE 13. *Frequency distributions of head length and body depth expressed as percent standard length in specimens of* Helicolenus dactylopterus *from the Atlantic Ocean.*

	Head length							*Body depth*								*Size range mm. S. L.*
	37	*38*	*39*	*40*	*41*	*42*	*43*	*29*	*30*	*31*	*32*	*33*	*34*	*35*	*36*	
Helicolenus d. dactylopterus																
Northeastern Atlantic	—	—	—	1	3	3	1	—	—	—	—	2	3	2	—	63–250
Gulf of Guinea	—	1	2	3	9	5	3	—	3	5	6	5	3	1	—	30–195
South Africa	—	—	—	1	1	—	—	—	—	—	—	2	—	—	—	163–164
Northwestern Atlantic																
Atlantic United States	—	—	1	5	2	—	1	—	—	—	2	3	—	2	2	40–231
Tortugas, Florida	—	—	2	12	17	11	2	—	1	3	12	14	9	5	—	60–185
N. Gulf of Mexico	—	—	—	—	1	—	1	—	—	—	1	1	—	—	—	101–158
Venezuela	—	—	—	1	3	2	—	—	1	—	—	2	3	—	—	84–322
Helicolenus d. lahillei																
Southwestern Atlantic	1	2	1	1	—	—	—	1*	1*	—	—	—	2	—	1	164–226

* Shrunk specimens.

Table 14. *Frequency distributions of orbit diameter and snout length expressed as percent standard length in specimens of* Helicolenus dactylopterus *from the Atlantic Ocean.*[1]

	Orbit diameter[2]							*Snout length*			
	11	*12*	*13*	*14*	*15*	*16*	*17*	*8*	*9*	*10*	*11*
Helicolenus d. dactylopterus											
Northeastern Atlantic	—	—	3	3	2	1	—	1	7	1	—
Gulf of Guinea	—	—	2	11	7	1	2	4	16	2	1
South Africa	—	—	—	—	2	—	—	2	—	—	—
Northwestern Atlantic											
Atlantic United States	—	—	3	4	—	2	—	4	4	1	—
Tortugas, Florida	—	—	5	17	11	6	5	13	28	3	—
N. Gulf of Mexico	—	—	—	2	—	—	—	—	1	1	—
Venezuela	—	—	1	2	—	3	—	2	3	1	—
Helicolenus d. lahillei											
Southwestern Atlantic	1	3	1	—	—	—	—	3	2	—	—

[1] Size ranges as in table 13.
[2] Smaller specimens average a proportionally larger orbit.

Table 15. *Frequency distributions of interorbital width and jaw length expressed as percent standard length in specimens of* Helicolenus dactylopterus *from the Atlantic Ocean.*[1]

	Interorbital width[2]					*Jaw length*					
	3.1–3.5	*3.6–4.0*	*4.1–4.5*	*4.6–5.0*	*5.1–5.5*	*18*	*19*	*20*	*21*	*22*	*23*
Helicolenus d. dactylopterus											
Northeastern Atlantic	—	3	3	3	—	—	—	2	4	2	—
Gulf of Guinea	1	1	14	3	1	—	—	7	13	3	—
South Africa	—	—	—	2	—	—	—	1	1	—	—
Northwestern Atlantic											
Atlantic United States	—	—	4	5	—	—	1	5	2	1	—
Tortugas, Florida	—	5	30	9	—	—	—	10	22	11	1
N. Gulf of Mexico	—	—	2	—	—	—	—	—	2	—	—
Venezuela	—	4	1	—	—	—	—	1	4	1	—
Helicolenus d. lahillei											
Southwestern Atlantic	—	—	1	4	1	2	3	—	—	—	—

[1] Size ranges as in table 13.
[2] Larger specimens tend to have proportionally narrower interorbital widths.

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